16

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.

THE HAGUE, 1894.

5th QUESTION.

Tolls on Navigable Ways.

REPORT

BY

HANS HATSCHEK, DR JUR.

THE HAGUE,
Printed by Belinfante Bros, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

Prof. W. Crane Watson

VI[th] International Inland Navigation Congress.

THE HAGUE, 1894.

Tolls on Navigable Ways.

REPORT BY

HANS HATSCHEK, Dr. jur.,

Chairman of the Magdeburg Chamber of Commerce.

I must unfortunately commence this report by excuses, for being called at the last hour to replace as reporter for Germany Mr. STRÖHLER, the Director of Railways and Navigation in Berlin, from whom it was at first hoped this work would emanate, I recognised immediately how great would be the difficulty of a profound study of the question. In fact it appeared impossible in the short space of time remaining to collect the tariffs of all dues in force and to become acquainted with all the various data, which have been gathered concerning canal dues and other questions of the same kind. Besides this the exercise of my usual functions and other literary work left me very little leisure for the preparation of the present report.

Nevertheless, I did not believe it my duty to decline the friendly offer of the charge, being convinced that my work would, in spite of its deficiencies and its insufficient data and although restricted to principal questions, still find favour with the Congress.

It is with pleasure also that I have drawn upon the reports presented from other countries to the Paris Congress.

I have found among them some valuable information. I have likewise made use of the fact that the question of tolls on fluvial ways was debated on several occasions last year in Prussia.

In this way I have found it possible to insert in this report some communications which will not be void of all interest even for other assemblies.

The question whether the existence of dues on navigable ways (I employ purposely this current expression in order not to enter immediately on the discussion of the designation of these dues as Customs

dues or taxes; my opinion on this subject is given in the first part of the report) rests on a good foundation has not been treated here more than was necessary, as I consider it has been resolved by the debates in Paris.

I have taken the liberty of treating more amply the question of the amount of these dues and other points named as being debatable at the present Congress. As regards other countries I have been able to refer to the data of the work of the Paris Congress. That which I advance concerning the situation in Germany is based on statistics, official as well as private and the communications which I have received are most reliable and are derived from the best sources.

I have the pleasure and the agreeable duty of returning my hearty thanks for the documents which have been kindly placed at my disposal.

To the representatives of the Central Berlin Union for the improvement of River Navigation; to Mr. Emil Andraea, ship-owner of Magdeburg and Mr. Geck, engineer of Hanover, whose experience has been of great assistance to me in various instances, and finally to my colleagues Mr. Gothein of Breslau, Dr. Wermert of Halle, Mr. Hirschberg of Bromberg and Mr. Simon of Königsberg, who have so obligingly obtained for me tariffs of dues and other documents.

Perhaps in judging this report with the indulgence which I solicit for it, my readers will find, in spite of all its imperfections and deficiencies some things useful to render more clear the question we are studying.

(*signed*) Hans Hatschek, Dr. jur.

Magdeburg, May 7th 1894.

I. FUNDAMENTAL QUESTION, CHARACTER OF DUES ON NAVIGABLE WAYS.

The 5th International Congress at Paris has already examined the question of tolls and taxes on canals. It has expressed as a principle that navigation should be as far as possible exempt from all impositions. But it adjudged admissible the establishment of certain dues in cases where means were wanting to cover the cost of extensions required by navigable ways.

This resolution of the Congress, regarded as general, was the opinion of the majority, if not of all of the delegates. A great number of them voted for the complete liberation of navigable ways from all impositions.

If we analyse the resolultion of the Paris Congress and the debates to which it gave rise, we draw the following conclusions:

1st Dues are admissible under certain conditions.

2nd They are only admissible in default of means for the extension of navigable ways, or for the construction or improvement of a navigable way.

3rd The dues collected are destined solely for the execution of works on navigable ways.

Besides this, all the delegates having adopted the resolution, were unanimous in acknowledging that dues should never take the nature of a tax, that they should never be a source of revenue to the State, but should only help to cover the expenses connected with the navigable ways. Without entering deeper into this general question, which has been so entirely solved by the Paris Congress, I think it still my duty to add briefly my opinion. In the first place I must state that I entirely share this opinion that navigation dues should never become taxes, but that dues levied for works of canalisation are admissible on account even of the urgency of these works. It appears to me to be right, also, to consider differently the question of dues accordingly as it refers to private navigable ways or to ways of communication constructed by the State (or the communal committees, provinces, districts and communes).

While as regards the first, the dues collected furnish the interest of the capital as well as amortisation and public interest is not concerned except in so far as it is necessary to guard against any abuse of monopoly in an undertaking of this nature, in the second case on the navigable ways of the State (and by this word I include works of communal committees, provinces, districts etc.) it is public interest alone which has to be taken into consideration.

The State or the communal committees should build canals, render the rivers navigable or regulate their course, when it is a question of general interest, but not when it is a matter of speculation.

The return of a canal, which is for private persons of first importance should be for the State merely a secondary consideration and then only when the parties interested themselves benefit by the tax.

But who are the parties interested? Not only the persons who navigate the way, but their supporters, industry and commerce, which feel the advantage of the diminution in prices of transport on the navigable ways.

Certainly the manufacturer or the merchant cannot pay this tax directly in the shape of a navigation toll on the canalised ways; at least this measure would present very great difficulties, for it would necessitate a search for the unique freighter etc.

For this reason the dues are imposed on the person using the canal, who can arrange that they are shared at least in part, by means of the freight, by his supporter, who is certainly in some way an interested party and perhaps even the principally interested party in the affair.

This therefore is the basis of the establishment of navigation dues. The due is not imposed for the benefit of the persons using the waterway and can consequently not be regulated with regard to the prosperity of their affairs. Neither is it compensation for expense occasioned to the founders by the construction of the canalised way; consequently it cannot be based on the cost of construction of the canalised way or any part of it. If this principle were admitted the dues imposed would have to be much higher on canals, the construction of which had been costly and would have to be raised for each part of the canal the respective construction of which had caused great expense. No reason exists for any such system if we lay aside the question of convenience and practical execution. The only right principle seems to me to be rather that the dues are a tax resulting from the profits of the canalised way and its navigation.

The navigation and indirectly those interested in navigation have to pay only for the economical advantage which the canalised way affords them; for the other part is borne by the State, which has to take into consideration the public interest connected with the construction of the navigable way, the benefits which will be eventually realised by other branches of industry and the common taxes which are enforced by these facts.

In one word, navigation dues should be a tax, not for the use of navigable ways and their plant, but a tax for the general economical utility of navigable ways.

In this way we regard the dues as a contribution towards taxes, which according to these principles should not press too heavily on those interested, but be a sort of participation on their side.

In cases where the dues are so high that the natural benefit resulting from the much lesser cost of transport by water, compared with transport by land, is lessened, or even entirely disappears, the dues are false

and unfounded; the economical advantage disappears, as a due is claimed for which no compensation is given.

In this manner we may take as a basis the general principle of a tax for economical advantage and deduct from it the principles necessary for the regulation of dues, their suppression and several other questions.

Among the questions to be here discussed that of the amount of the dues and their limitations seems to me to be the most important. On the one hand the amount depends on the construction and on the prosperity of the navigation; on the other hand, precisely in regard to this question of the amount of the dues, there has been lately — at least in Prussia — a demand made for a higher tax on navigation, at a time when the railways are endeavouring to take away as much traffic as possible from navigation by reducing their tariffs often to cost price and sometimes even below it. In conclusion, I will observe that the continuation of this report will treat only of navigation dues. The question of port dues and dues for the use of navigation plant is here neglected on account of the divergence of these subjects from the principal subject, as well as for want of data concerning tariffs of ports etc.

II. AMOUNT OF DUES. UNIT OF THEIR APPLICATION.

In accordance with the remarks already made we possess the elements for solving this question.

The bases of limitation and fixation of navigation dues (we are of course understood always to speak of canals and navigable rivers) are derived from, on the one hand, the first principle expressed, viz. a tax that may be imposed on interested parties for the expenses of establishment and working, for interest on and amortisation of the capital, and for expenses of maintenance and management; and, on the other hand, in accordance with the second principle expressed above that the dues are merely an indemnification, a tax for economical utility.

The limits of the amounts of dues may be fixed on the one hand by taking into account that the State (we do not speak here of private navigable ways for which there are other rules which we shall mention later on) will take upon itself a part of the expense; and on the other hand, the fact that by the payment of these taxes the parties interested reserve to themselves an economical advantage. The first principle which we have expressed has been until lately unanimously accepted; its application also always gave a good result, inasmuch as it was admitted that the amount of the tax should only reach the sum necessary to cover the expenses of maintenance and management and at the most render a moderate return to the capital.

One of the reporters at the Paris Congress, Mr. Sympher, Inspector of

Navigation Construction, stated in his report that the total of the sums devoted by the German government to the maintenance and management of navigation ways during the years 1881 to 1890 amounted to an average of about 12 millions of marks, and this total only differs from that of the amount received as dues by 2 millions of marks. For Prussia alone, Mr. SYMPHER gives an excess of ordinary expenses over receipts of 6.5 millions of marks and that with a total outlay of 8.3 millions of marks; there is here no question of unforeseen expenses.

I have been allowed to have at my disposal a document (1) communicated by the Prussian Government to the Commission on the Budget in Parliament treating the subject of the canalised ways of the Kingdom on which tolls are collected for the benefit of the State. It appears from this document (See Annex I) that the expenses of the maintenance and improvement of these canals reached in the years 1889 to 1891 a capital of 78,063,928 marks, for the technical part, and the collection of tolls on the canals and foreseen expenses to 1,375,166 marks.

The interest at $3^1/_2$ $^0/_0$ on the capital and the amount of expenses of management and maintenance would give together 4,107,404 marks, while the total receipts collected were 1,160,999 marks and thus less by 214,167 marks than the total of the expenses of maintenance and management.

These figures agree with those given by Mr. SYMPHER.

They present again a deficit in dues received, as compared with expenses of maintenance and management.

That the difference shown here is not so important, is explained by the fact that the expenses only of canals on which tolls are levied are mentioned and not the total expense of maintenance and management of all navigable ways. Besides, in the figures given by Mr. SYMPHER is included a sum of 732,000 marks derived from the collection of port dues.

It is very clear from these figures that up to the present neither Prussia nor Germany has had the intention of drawing from the navigation dues levied on canalised ways any interest or amortisation whatever for the expense of construction.

The same was likewise said in Paris by the reporter from Holland, the chief engineer Mr. DEKING DURA, as well as by others from different countries.

France, where canals being the property of the State have been hitherto open free to traffic, and England, which suffers from a want of navigable ways, being left out of account, I believe I may state, that up to the present time no country has any intention of drawing from a fiscal

(1) For the use of these very interesting data I am indebted to the kindness of my respected colleague Mr. GOTHEIN of Breslau.

point of view any return whatever from its canals, but merely the sums necessary for their maintenance.

In Prussia the views of the Government have so much changed that on certain canalised ways, for instance on the canal of the county of Marck between the Elbe and the Oder, the tolls, which were formerly not high, have been raised so much that it is estimated that this augmentation of receipts will cover, not only the expense of maintenance, but also a part of the interest of the capital.

According to the above mentioned document, notwithstanding the moderation of the estimate, the receipts of the canals of the county of Marck for the year 1893—94 will amount to

1,017,758 marks, against
873,285 marks for expenses of maintenance and management, and
1,938,289 marks, amount of interest on the capital engaged at $3^1/_2$ %.

So that there is a surplus of 144,473 marks over the expenses of management and maintenance.

That is according to the estimate of parties interested, but probably there will *be still much more.* For the great canal now projected from the Rhine to the Elbe there is a prospect of heavy navigation dues, which will *much exceed* the toll of 9 pfennigs per kilometric ton, the toll spoken of by Mr. SYMPHER and which is about the average toll in force on canalised ways at the present day.

It is calculated that with these higher tolls and the probable navigation there will be found a return of $3^1/_2$ % on the capital.

Persons interested in the canal named the Mittelland Kanal (which will run from the canal from Dortmund to Emshafen, now in course of construction, to the Elbe and the Weser) have in a report (1) proposed and demonstrated the utility of raising the tolls by 5 pfennigs per kilometric ton, which will give for the canal an interest on the capital of $3^1/_2$ % and an amortisation of $^1/_{10}$ %.

In the project recently submitted to, and unfortunately rejected-by, the Prussian Landdag of a canal from Dortmund to the Rhine, the basis was formulated on a toll of 1 pfennig per kilometric ton.

According to the opinion of the Government and many interested parties, these dues would be sufficient to produce and even assure a return on the canal. At the time of the discussion on the project of this canal the conservative party emitted the following resolution.

That the Government should be requested:

1st. When fixing canal dues to take into consideration the covering of

---

(1) »*Der binnenländsche Rhein-Weser-Elbekanal nach den neuen Entwurfen*» commissioned by the «Verein für Hebung der Fluss u. Kanalschiffahrt für Niedersachsen» in Hanover, and published by FRITZ GECK, Engineer, Hanover, 1894.

the expense of management and maintenance and of a corresponding interest on the capital, and to make a trial of the application of the principle *to the tolls on existing canals* in so far as it may be practicable, to unite it with the conditions of agriculture and traffic.

2nd. To take into consideration the establishment of taxes destined to cover expense incurred by the improvement of natural waterways.

After the minister of Finance had in the course of the debate declared that the general idea of this resolution was right and that it was shared by the Government, it was witdrawn, because, as was said by a delegate in the name of his party, the object of the resolution was found to be fulfilled by the declarations of the Government.

If we consider that the Prussian Government has up to the present remained deaf to all claims concerning the said elevation of navigation dues on the canalised ways of the county of Marck and that according to a declaration of the Minister of Finance to the Parliament the question of tolls is about to be examined by the Government (certainly not with a view to the reduction of dues), we may be convinced that the views of the Prussian Government are changed.

The opinion of the representative body is also changed. While in the year 1886 it voted all the Rhine—Weser—Elbe canal, at least in the sense that „the Government was authorised to apply so many millions of marks to the establishment of a navigable canal destined to connect the Rhine with the Ems and the Elbe with the Weser in the way most beneficial to these rivers; and later to the construction of the canal from Dortmund to the lower Ems", we see that a few days ago it rejected the project of the construction of a canal from Dortmund to the Rhine, that is of a part of the Rhine—Elbe—Weser canal which was decided on in 1886.

The causes of the rejection are principally, apart from a few purely political questions, an agrarian agitation in the East which, astonishing as it is (it may, nevertheless, be attributed to the withdrawal of certain railway tariffs favourable to the east) at a time when agriculture is in want of canals, has become an adversary to navigable ways.

But apart from this, which emanates from the management of the State railways, a current of opinion has been raised in certain circles favouring a severe fiscal tax on navigable ways, and this unfortunately also in competent circles, and a very interesting political campaign of railway tariffs is opening in direct opposition to navigable ways.

However interesting and useful it might be I will not dwell on this subject; it is the question of navigation dues only with which we are now concerned.

This question, as we have said, has certainly been regarded in Prussia in a new and different light, which tends to seek in canal dues a complete return for the interests of the capital devoted to the execution of the works.

With regard to the tendencies of the Governments and Parliaments of other countries, I will not allow myself to judge them. Perhaps the delegates from these countries will give us some information on this subject.

England is not interested in the question, as the State does not possess any canals. In France, as far as I could deduce from the debates at the Paris Congress and from other indications, the treasury appears to raise certain claims. In any case we have here full reason, as an International Inland Navigation Congress, to occupy ourselves with such indications.

But let us return to the principle of the amount of navigation dues.

It is, in my opinion, as I said above, thoroughly unjust to endeavour to draw from navigation dues the complete interest on the capital.

It is much more reasonable that the State, as the party taking the management of the canal, be charged with a part of the interest to be produced; for the canal, when it is a canal having a *raison d'être* (and if a canal has no *raison d'être* it should never be constructed), does not only benefit the parties directly interested, but also the State and other branches of the population belonging to absolutely distinct branches of industry.

In constructing a canal the State performs a work which, far from leaving it indifferent, concerns it and the mass of the population, as also the welfare of the State and of the public.

It follows from this that it is incumbent on the State to support, at least in part, the expenses of the work.

An important canal brings profit to the State, for in proportion as commercial relations are developed by this canal, the taxable resources of the parties interested in it increase and new enterprises are formed, which are liable to be taxed by the State, the fiscal receipts of which are thus augmented.

This indirectly benefits other classes of the population, for the canals are of great importance to agriculture; giving every possibility for the adoption of improvements, they cause a rise in the value of large fields sometimes of many millions; and finally, owing to the moderation of their prices of transport all classes of consumers benefit by the canals, receiving by their means products of which they are constantly in want, such as coal, wheat and iron.

Besides this, social economy is benefited, for products localised in one place are promptly decentralised, the distribution of production becomes equal, especially as regards the demand for coal, the transport by boat, economical, but less rapid, giving rise to more uniform orders.

Finally, if we consider that in case of war each canal has to play its part, will be utilised for transports or for the establishment of military hospitals, the removal of which would thus be more easy, it must be acknowledged that the advantages which the State may derive directly or indirectly from every canal of any importance are really numerous and of great consequence.

The only question which might be considered by the State before proceeding to the construction of a new canal would be a deficit in the receipts from railways in countries where the whole or a considerable part of the railway system belongs to the State.

I will not go further into this question, which has already occupied several Inland Navigation Congresses and has recently been frequently discussed in the Prussian Landtag, as well as in other assemblies and in the press. Only this should be said: even if we do not thoroughly support the view of complete harmony of interests between railways and navigation, which has been so often talked of, the advantages which a large new waterway offers to railways are so important, that a loss to them of some freight (which is the natural consequence of the construction of a new way of communication) is nearly, if not entirely, compensated.

In fulfilling their rôle as agents for the bringing of traffic to the canal, the railways attract a great deal of new freight and burdens are taken off the railways, which they themselves would scarcely care to carry or at least not without increase of the means at their disposal.

The canal gives birth to new enterprises and to new commerce, which contribute also to the prosperity of the railways. Thus, the case of the damage caused by a canal to the State railways is not very defensible.

We may, however, considering the consequences which the construction of a canal might have for the State railways, contest the principle that the State should derive from navigation dues, not only the cost of maintenance, but likewise all the intrest of the capital engaged.

From this it follows logically that it may not claim from the interested parties a guarantee of this interest until the amortisation is complete. A certain guarantee may, however, be with all justice demanded and is also reasonable, for the directly interested parties have a right to expect the first as well as the last advantage and the great interest attached to the construction of the canal will even be strengthened and assured by this guarantee.

A guarantee of the entire return would be especially unjust in a State possessing its own railways, because in this case the interest which the State must necessarily have in the return of the canal would be lessened and the danger might arise that the State should menace the canal in the matter of tariffs and thus lessen the navigation of the canal the return of which was guaranteed.

Even when the return of the canals appears guaranteed with the existing railway tariffs, the interested parties are not in a position to take over the undertaking or to guarantee the complete return, so long as it remains possible that the canal and its commerce may be injured, for instance by exceptional tariffs at less than cost price for transports on the railway running in competition with the canal.

It is worthy of remark that the Prussian Minister of Finance, Mr. MIQUEL, expressed his opinion in the same sense in the Prussian Landtag during the course of the debates concerning the canal from the Rhine to Dortmund. Besides, in the case that the complete interest on the capital sunk in the waterway is covered by the dues levied or guaranteed to the State, it is very doubtful whether there be any justification for granting to the State a monopoly with regard to canal construction; or if it should not rather be left to the parties interested, as is done in England, America and other countries, at least in countries with a large railway system, under the guarantee of the State as regards rates of tariffs, which might compete with the canal.

In any other circumstances, as will be seen by the considerations above mentioned, the establishment of a canal by private persons is not possible.

I will return now to the consideration of the first principle, the amount of navigation dues.

From certain considerations, which we take as principles, these taxes may not be so high as to entirely cover the interest of the capital, as the navigable ways are directly and indirectly a source of great advantage, so that it is only just that the State should be responsible for a part of the expenses or for the interest of the capital.

With regard to the amount of navigation dues the second principle, equally important and self explaining, is that the amount must never become so high that the natural advantage resulting from the moderation of prices by water compared with prices of transport by land may be lessened or disappear.

In other words, the taxes may not in any case increase the price ot transport by water to such an extent that it would no longer be possible to compete successfully against a well-directed arrangement of railway tariffs.

A canal which could not be constructed without such great expenses should not be undertaken, because in that case, the principle object, viz. *cheap* transport, is not attained.

To what extent may canal dues be raised in order to successfully compete with railways, is a question which must be decided according to the manner of the competition between the canal and the railway and according to the extension of commerce which may be expected.

In all the projects concerning the canal from the Rhine to the Elbe and the Weser (probably with a view of obtaining an interest of 50 %) a canal due of 8 pfennig per kilometric ton is charged.

In the above mentioned report on the Mittelland canal a toll of ½ pfennig is recommended as sufficient, and in the proposal for the canal from the Rhine to Dortmund (compare page 28) the Government held in view a toll of 1 pfennig per kilometric ton and also established in opposition to the railways the following tariff:

For coal and coke is levied a canal freight of 1 pfennig and a toll of the same amount, and the charge per ton is placed at:

For a distance of:	By railway:	By canal:
10 Kilometres	0.80 Marks	0.20 Marks.
15 "	1.00 "	0.30 "
20 "	1.10 "	0.40 "
30 "	1.50 "	0.60 "
40 "	1.80 "	0.80 "

and by taking as base 5 pfennigs per kilometric ton on the branches for a distance on the branch of 4 kilometres:

For a distance of:	By railway:	By canal:
8 Kilometres	1.05 Marks	0.36 Marks
19 "	1.38 "	0.58 "
26 "	1.55 "	0.72 "
32 "	1.68 "	0.84 "
35 "	1.78 "	0.90 "
54 "	2.63 "	1.28 "

Supposing these figures to be right for freights by rail and by canal, we see that the canals could always compete successfully with the railways with a toll of 1 pfennig per kilometric ton.

The normal tariff actually in force on the railways, amounts, at least for coal, to 2.2 pfennigs per kilometric ton and 6.12 pfennigs for shipping dues. A few special tariffs have gone lower than these figures, which however are not perceptibly higher than the canal freight of 2 pfennigs augmented by the canal dues.

The canal freight ought really to be a little less than fixed above (1 pfennig per kilometric ton).

On the Mittelland canal it is in the report of the interested parties calculated at 7 pfennigs.

It is unfortunately impossible to regulate the dues on the navigation ways in Prussia on a unit of 1 kilometric ton, for all these dues are established according to the tonnage of the ship and not according to its real cargo and only collected at certain locks without the distance traversed being in any way calculated in the amount.

According to the calculation of Mr. Sympher the sum paid on canals where tolls are levied is only 2 pfennigs per kilometric ton. If we take into account the recent increase in these dues on the canals of the county of Marck, which on the average must be estimated at much more than half of the amount hitherto charged (see particulars below), the average of dues on all navigable ways will certainly amount to 4 or 5 pfennigs, if not more.

From what has already been said it may be concluded that it is nearly impossible to establish for the dues a uniform unit which would fix

exactly the amount to which they might be raised without danger to the vitality of navigation.

This depends again too much on the economical conditions of the region and of the possible and probable extension of traffic etc.

Leaving on one side possible cases of exceptionally prosperous traffic a unit of dues of from 2 to 5 pfennings may be considered as possible.

For canalised ways of less dimensions and of insufficient construction this unit will be found to be amply sufficient, as such navigable ways do not admit large vessels with lucrative freight.

With this question is connected the system, which we will study later on and which is easy to apply, of a navigation tax based on the tonnage of the vessel.

A question which also attracts much attention is the increasing of dues on a waterway which is already in working.

I may be allowed to touch upon this subject.

If a canal has for some time been levying certain fixed and invariable tolls on its navigation it is probable that these tolls have been taken account of in the calculation of freights; the navigation has thus acquired the power of supporting these taxes, for what has been found to be above its means has been placed to the charge of the freighter in the price of the freight.

But if an increase of dues takes place when the freights have been long fixed, it is invariably very difficult for the boatman to comply with this new state of things without himself supporting the increase. Therefore an increase of dues is only equitable in cases where new expenses for the welfare of the canal render it necessary and the State requires a much larger amount for maintenance and interest on the increased capital.

But even in this case it is desirable that a notice should be given at least about six months before the new tariff takes effect, in order that running contracts and freight calculations based on the former tariffs may not cause heavy loss to those interested in them.

In concluding this part of my report I would add a few words on the subject of dues and their amount on waterways which are private property.

In the above remarks we have continually referred to canals belonging to the State (Provinces, Communes, etc.) which have their own particular interests and on which the conditions are quite different to those existing on private canals.

The reporters at the Paris Congress in treating the question of dues on navigable ways which are private property, have drawn the conclusion that the dues should cover the complete return of the interest of the capital.

It is unnecessary for me to express an opinion on this general question. Nevertheless, as regards the amount of dues, we may fix the rule that

on canalised ways which are open to the public (and with such only we are now concerned) navigation must not be hindered or rendered difficult by measures emanating from private persons.

It should also be insisted upon that on canalised ways constructed and worked by private parties and according to law open to the public, the State has a right of control with regard to the levying of tolls. The State should have the power of fixing a certain maximum of tolls in proportion to the capital and be able to prevent any arbitrary measures being imposed.

It is true that the owners of the canal in their own interest would avoid an excessive demand of tolls, still it is advisable to take into consideration the possibility of such an abuse of the monopoly and for this reason we refer to the question.

I will now offer some observations relative to the amount of dues and the basis of their unit:

1. *Navigation dues on a canalised way belonging to the State (communes, provinces, etc.) may not be so high as to bring into the State the entire interest and the amortisation of the capital and still less to allow it a profit on the speculation; for every canal which is really of service — and only such should be constructed — gives rise to such direct and indirect profit to the finances of the State that it is only right that it should forego a part of the interest on the capital.*

Also the interested parties must only be expected to partly *guarantee the interest on the capital.*

2. *The amount of the dues is limited by the consideration that the price of transport by water, although increased by the navigation dues, must still remain essentially less than the lowest rate of competing railway lines. The natural advantage of the canal resulting from the moderation of the prices of transport must not be reduced by excessive dues.*

3. *The basis of the unit of navigation dues is to be determined according to the respective conditions of the waterways. According to observations made up to the present day, leaving on one side particular cases and situations exceptionally advantageous, the dues should scarcely exceed* 2 *to* 5 *pfennigs per kilometric ton. The unit must be less where the waterway is less able to bear the charge.*

4. *Great care should be exercised in applying any increase of dues to a canal which has for a long time been used for navigation. Such increase is only justifiable in a case where important expenses are necessary for the improvement of the navigation of the canal.*

Again, attention must be given to the case of owners who are unable by means of their freight to cover this increase of dues; and in any case, they should be advised by circular about six months before any such alteration is put in force.

5. *With regard to navigable ways undertaken and directed by private parties the state retains the privilege of controlling the establishment of dues*

and of their collection. Although the principle of levying dues for the entire interest on the capital be admitted, the State should have the right of fixing the maximum of these dues so as to obviate any possible abuse of monopoly.

III. CALCULATION OF TOLLS.

Apart from the question of the amount of the dues, that of their *calculation* has its particular importance on the one hand, because the levying of heavy or light dues may be sometimes crushing and at others supportable, and on the other hand because it is only by rational calculation that an equitable division of the dues can be guaranteed. Hence arise several distinct points to be debated in this part of our report.

In the first place there is the general question should dues for the navigation of waterways (as we have already said, we will refer later on to Port dues etc.) be collected in the form of one single tax, or in the form of tolls for the use of locks, lifting machinery etc. or perhaps in both ways.

The other questions relate to the principles of the calculation of dues and the different systems which may be adopted, such as calculations based on the tonnage, on the real cargo of the vessel, on the nature and value of the cargo, on the distance traversed, etc.

Then there is the question of the abolition, of the moderation of dues and of the levying of special dues; and finally the question of collection and control.

Another part will be devoted more particularly to floats.

A. Collective dues or partial tolls.

This question is comparatively easy of solution.

If we admit the principle of collection of dues for the use of a canalised way as compensation for economical advantage resulting from it, it follows that these dues should be levied for the use of the canal as a total and not only for the use of the various navigation plant, locks, levers, etc.

The economical advantage afforded to persons using the waterway consists in the faculty of using the whole or a part of the canal as a means of transport and not in the passing through a lock, or of having recourse to the services of any apparatus.

The boatman cares little whether be has to pass through many locks or no locks, his object being to reach his destination at the end or on the course of the canal.

On the contrary, a number of locks cause delay on the journey and therefore it is less profitable than when there are few or no locks at all.

Thus, although the principle of regarding lock-money as compensation for expense caused may be right, it cannot be admitted in this idea of general economical advantage, and one total and general toll for the use of the waterway is much more just.

The same reasons which apply to economical advantage must also have an influence in the calculation of dues, such as the quantity of cargo carried, perhaps also in some degree the nature of the cargo, the distance traversed on the canal, etc.

This calculation of the dues into one collective and general toll for the use of the canal has a great advantage over the levying of tolls for locks, lifting machinery etc., in that it is much more equitable.

It obviates the inequality resulting from the fact that one boatman may on perhaps a much shorter journey have to pass through twice as many locks as another, and renders systematic the levying of the tolls which might otherwise become arbitrary or dependent on accidents.

It may be also the means of collecting in a more just manner the money necessary for special expenses, such as locks and lifting machinery and thus there would be no question of these being gratuitous.

On the other hand, a toll would be levied in a reasonable manner on boats using those parts of the canal on which there are no locks.

It does not follow from this that the levying of a special toll for locks in addition to the general toll is to be in every case excluded.

A case might occur in which the construction of a new and larger lock would be dependent on the imposition of a toll for this purpose. Perhaps in such a case it would be justifiable to claim from those who use this new construction, built expressly for them, a special lock due and that especially in a case where a general increase of dues would be inadmissible.

B. Sytems hitherto in vogue for the calculation of dues.

As it is now only a question of determining the true basis of the calculation of dues we must naturally first consider according to what principles and if possible according to what systems we should proceed in calculating dues on canalised ways in the countries where such dues exist.

From this the different systems of calculation of tolls may be determined and we may base on this material an examination of each particular system and of the entire question with the view of recommending one or the other of them with or without alterations.

We will attempt in the following reflexions to determine this question.

The calculations of dues, fixed in former times on taxed waterways, were very different. This is explained perhaps partly by the fact that the composition of the tariff was not guided by theoretical principles, and partly because the theoretical fundamental ideas were influenced by

various practical considerations, and finally the conceptions of the character of the dues were very various.

Accordingly, as the dues on waterways were considered as a tax on the traffic or as a toll for the use of an organisation directed by the Government, very various principles for calculation of dues in different countries have been suggested and amongst them the already mentioned practical considerations of facility and certainty in collection.

The country which above all others, has favoured the imposition of navigation dues in the form of a tax upon the water traffic is Russia, where nearly throughout the country, at least until very lately (some reform was projected in 1892), dues were levied on the value of the goods transported and then, according to circumstances, in most various ways, as for instance $^1/_4$ $^0/_0$ on the canal from Sebesch to the Dwina, 1 $^0/_0$ on the Dniester etc. (1)

Besides these, there are in Russia dues fixed according to certain calculations per ton. On the other hand the distance traversed is not taken into consideration.

Every boat entering the canal has to pay dues, either according to its tonnage or the value of its cargo without reference to the distance traversed.

And this system is absolutely unjust for the following reasons:

a. It is a tax on commerce, because it is based on the value of the goods; *b.* it does not take into account the distance traversed or to be traversed, and because *c.* the calculation of tonnage and of value being furnished by the owner himself is, as will be easily understood, very unreliable; and this has been already acknowledged in Russia.

Numerous propositions have been made, among them that of the permanent commission for the examination of questions relating to inland navigation, which suggested the levying of dues on steamboats in proportion to their force of impulsion (number of horse power), otherwise according to the cubic measurement and the draught of the vessels, or according to the tonnage of the goods carried, which should be divided into at most three classes, or according to the distance traversed, or according to the number of passengers, or the distance they travel.

The commission was averse to the imposition of any dues, which were not to be devoted to the improvement or maintenance of the navigable ways, and was thus unfavourable to any tax on traffic.

We do not know how the question has been solved in Russia.

Holland has viewed the question in a different light than Russia has done (2).

---

(1) These data are taken from the report of Mr N. von Sytenko to the Inland Navigation Congress at Paris.

(2) Taken from the report of Mr Deking Dura to the Paris Congress.

In Holland the dues levied on canals belonging to the State have completely the character of tolls and are really nothing but a compensation for benefit derived.

They are levied according to the cubic measurement of the vessel without regard to the nature of the goods carried, at the most with exemption from toll or from half of the toll for empty boats or for boats with certain classes of cargo, such as manure and dung. The levying of dues in their intirety has, however, been projected for all canals where dues are imposed. On many canals they have been already entirely abolished. Still, the dues levied by the communes, the provinces and the companies called *Waterschappen* would remain in force. The distance traversed is not taken into consideration, and the due fixed is only levied at the passing of locks and bridges in accordance with the cubic measurement of the vessel, which is either gathered from official documents or is calculated. The tariffs are moderate, averaging only 5 cents per cubic metre.

In France (1) all tolls on canals belonging to the State were abolished by law in 1880. Before that time there existed on some conceded canals (the Briare canal, for example) dues calculated on the tonnage of the goods and on a unit of distance of 5 kilometres, that is on a system which took into account the distance traversed. Later on a general navigation due calculated specially for each canal was introduced.

A law of the year 1837 established on all canals and rivers a simplified and uniform due still calculated by the ton and the unit of 5 kilometres.

At present there are about 805 kilometres of canals and canalised rivers, *not* belonging to the State but „conceded", on which dues are calculated on the same system of toll collection according to the kilometric ton and *the real cargo.* In a few isolated cases tolls are levied at locks, as on the St. Denis and the St. Martin canals, without regard to distance traversed.

On a few of these canals the tariffs make mention of only two classes of goods, while others have extended tariffs for all sorts of different merchandise.

In Germany, where the dues formerly in force on the Elbe, as a last vestige of taxes on fluvial commerce, were finally abolished in 1870, there still often exist some dues for the use of canals, the majority being in the form of lock dues.

Navigation dues for large canals projected or in course of construction have also been under consideration.

The constitution of the German Empire does not authorise dues on natural navigable ways, except for the use of material or plant established

---

(1) According to the report of Mr L. Couvreur to the Paris Congress.

for the facility of the traffic; and in the same way, as is the case with the artificial navigable ways belonging to the State (canals which are private property are not referred to), only such dues are allowed as do not exceed the expenses necessary to the establishment and maintenance of the service.

In different German States, numerous laws and regulations relating to navigation dues on artificial ways have been decreed, but all based on the spirit of this constitution. It is only in the Grand Duchy of Hesse, in Wurtemburg, in Hamburg and in Alsace-Lorrain that there are no dues on navigable ways.

The regulations and tariffs established for the calculation of dues in Prussia, in Bavaria, in Mecklemburg and in other German States, are of a very different nature.

I must refrain from thoroughly analysing them here. (See the tariffs in Annexes II, III, IV and V, and the report of Mr Sympher to the Paris Congress).

The basis of calculation is nearly always the tonnage of the vessel. The toll is calculated on a unit of 5 tons burden. The Bavarian canal from the Danube to the Maine is an exception to this system, for the real tonnage of the cargo is calculated in the same way as it was on the canalised Saar up to the time when the dues were abolished.

In some navigation tariffs 10 and sometimes 12 net cubic metres are spoken of instead of 5. The system is however the same.

The distance traversed is not taken into account except on the canal from the Danube to the Maine (Ludwig Canal) and a toll only is levied at different locks, according to fixed and uniform tariffs.

For the most part, the nature of the cargo is not taken into consideration, except for the distinction of a few classes, such as raw material, stone, coal, ore, etc. and manure, which have only to pay one half, or at least a very low proportion of the usual tariff.

We may mention as characteristic the rule existing up to very lately on certain navigable ways in Prussia, on the canals of Marck, according to which tolls were calculated up to a limit of 116 tons; larger vessels had only to pay a maximum due of 115 tons, although their tonnage was sometimes as much as 400 tons.

This rule was abolished on the Marck canals in 1892 as well as on some other canals, at the same time as the tariff of tolls was raised in such a way that the larger ships had to pay dues much higher than formerly.

This is more fully explained in the report of the Central Comittee on Inland Navigation of Berlin, the table of which we give in Annex VI.

With this generally ruling system of calculation according to tonnage some tariffs take into consideration the incompleteness of the cargo of the boats (caused by insufficient depth of water etc.), so that when the

cargo is less than one half, only one half of the dues are levied.

Empty boats for the most part pay one sixth and latterly even less.

Finally, there are certain exemptions from dues for vessels belonging to the State and for others which are not destined for the transport of merchandise, for small boats, etc.

For the present, we will not further pursue this subject.

Protestations have lately been repeatedly made against the system by persons using the waterway, as well as against some ways of calculating navigation dues in Prussia and principally in consequence of the elevation of dues projected in 1892. We will refer more fully to the subject of these difficulties when examining the different systems.

Finally, in England (1), where there are no canals belonging to the State, dues are in force on different canals.

The systems are very various.

There are simple lock dues and general canal dues per ton per mile. Usually the nature of the goods is classified into various sorts. Compared with those of the continent, the units are very high, varying between one halfpenny and two pence per ton per mile.

To my great regret it has been utterly impossible for me or obtain details of the dues levied in other countries.

But, although this sketch of tariffs and rules for the levying of dues has been given as concisely as possible (for details I must still refer my readers to the Annexes of the report as well as to those of the reports to the Paris Congress), it may be inferred that three different systems are in use, viz.

1st The calculation of dues according to the value of the cargo.

2nd The calculation in accordance with the tonnage and in proportion to the cubic measurement.

3rd The calculation in proportion to the real cargo carried and generally taking into consideration the distance traversed.

In the first system the nature of the goods is most fully considered, whereas in the second and third systems only certain classifications are given which are nearly the same. The distance traversed may be taken into consideration and combined with all the systems, although this has not hitherto been done under the first and second systems. We have, therefore, now only to critically examine these different systems and in connection with them the various important rules to be considered in the compilation of a tariff of dues.

---

(1) Report of Mr. Clements to the Paris Congress.

C. EXAMINATION OF SYSTEMS.

I. Examination of the principles of calculation.

From a consideration of the modes of calculation hitherto employed in various countries it is easy to determine which system can be recommended as the most fundamentally just, and at the same time practically useful.

From the fundamental as well as from the practical point of view the fixing of dues according to the *value of the cargo* should be *absolutely rejected*, even if these dues were moderate, but still more so if they complied with the requirements mentioned in the previous chapter. From the fundamental point of view, because dues established according to the value of the cargo constitute a tax on commerce and not simply a compensation for the use of the advantage offered by the waterway.

Besides, the value of the cargo could never be otherwise considered than in so far as it influences the amount of the freight, that is the *economical* advantage which the canal affords to the freighter.

But this is certainly not the case; even when certain articles of higher value are obliged according to their rule to pay a higher freight than masses of goods of low value, the amount of the freight and the value of goods are not in such even proportions that the value of the goods paying the higher tariff may be taken as a basis for fixing the freight to be charged on them.

This principle does not, however, require any further examination.

Also from a practical point of view this system must be absolutely put on one side.

It has proved in Russia, according to the reports made to the Paris Congress, very defective in practice.

In fact the fixing of the value of the cargo can only be effected in two ways, viz. either by an official valuation, or according to the declaration of the owner himself.

Both of these ways present difficulties and are very unreliable.

An official valuation by the means at present at the disposal of the administration of waterways and of their finance department, to which is confided the collection of tolls, is simply impracticable as their staff has not the requisite knowledge of markets and prices. But even if a competent staff of experts for the valuation of goods should be appointed, differences and claims would certainly arise from the diversity of the nature of the goods and of the continual fluctuations in the market prices. Also as the decision of the experts could not be left without right of appeal, long and tiresome proceedings would inevitably result. To this must be added the great delays which would be caused to traffic by this system of valuation by experts, the difficulty in its administration,

the uncertainty of a correct result on account of changes which might be caused by embarkment or discharge of cargo in the course of the voyage etc. Even if the amount for which the cargo was insured were taken as a guide nothing would be gained, for it might occur that some of the goods were not insured at all, or only covered by a general policy, and further, the amount of the insurance itself would probably be influenced by the consideration that the dues would be based upon it.

The estimation of the value according to the declaration of the owner would be equally impracticable.

Apart from the fact that for want of sufficient control a way would be left open to a wide field of fraud, the owner would often with the best of will be unable to furnish a reliable account of the value of his cargo. Neither could the bills of lading, which are frequently not taken on the boat, serve as a guide even if they contained any declaration of value. For these reasons it will be seen that an effective control is practically impossible and even the most superficial examination of the contents of the vessel would cause delay to traffic and result in great inconvenience.

It will thus be seen that, apart from fundamental considerations, the collection of dues on canals or other waterways according to the value of the goods transported is practically very unreliable and cannot be maintained.

The second and third systems are much to be preferred, basing the dues on the tonnage of the vessel and its cubic measurement.

In fact, a system of this kind corresponds much more with the fundamental principle of the due being a compensation for an economical advantage, for this advantage increases in proportion to the amount of the cargo or the size of the vessel.

Also, from a practical point of view this system is incomparably preferable. Its introduction will give the best results and be more easy of application. The size of the vessel and the quantity of the cargo are points which can generally be easily and correctly estimated.

The first point is determined according to papers of measurements now in general use and which are rendered obligatory. They show the exact measurements of the vessel and the boatman must always have them on board.

If these papers should be defective an approximate valuation can always be made by means of a comparison with other boats of the same construction, at least if the traffic be of any importance.

Apart from the consideration that a declaration by the boatman is more easy of control, there would be less likely to be any opportunity for fraud.

There are besides, other very practicable means of determining exactly the cargo of a vessel by reckoning its depth of immersion with the aid

of a specially constructed guage (See Annex VII). The calculation of dues according to the quantity of the cargo or the size of the vessel is used in two systems, both in calculation according to the *tonnage of the vessel* and according to the *tonnage of the cargo.*

As we naturally cannot expect to find the full tonnage of the vessel always utilised, there is an essential difference in the two systems.

The first is easy of execution, for as we have said above the tonnage of a vessel is easy to determine.

From a fundamental point of view it might be alleged that whether loaded or not vessels of all sizes equally profit by the canals and the works established on them. Likewise, it might be averred that the dimensions of artificial waterways are calculated especially as regards their least depth of water, according to the draught of the largest ships expected to use them when fully loaded, and that it is desirable that the dimensions of the canals be entirely utilised.

But these considerations are not consequent and do not agree with the principle indicated as the only correct one for the calculation of dues. For dues should be fixed not according to the use made of the canal or the works established on it, nor according to the expense incurred by affording facilities to larger vessels, but, as we have said above, directly in accordance with the economical advantage offered to owners. This economical advantage having no connection with the tonnage of the vessels, but on the contrary lessening as soon as the complete tonnage is not utilised, it results that the calculation of dues according to tonnage is incorrect and not in accordance with the fundamental principle we have indicated.

If this calculation has been used and maintained up to the present day in Prussia, it is because, in consequence of the existence of papers of measurement, it was practical and easy of application; and on account of the moderation of the units of tolls the injustice and inequality of the system were not so perceptible. There is, however, a strong current of opinion in Prussian navigation circles against the system.

By the *system of calculation of dues according to the actual quantity of the cargo,* the dues are justly higher in proportion as the cargo is larger.

The amount of the due is thus more in proportion to the economical advantage, for the latter undoubtedly increases with the increase in the quantity of the cargo, while by the system of taxation according to the tonnage of the vessel it lessens in proportion as the cargo decreases and the dues remain the same.

From the fundamental point of view this system is the most correct of all those which we have examined up to the present. To become absolutely in accordance with the principle of calculation in proportion to the economical advantage obtained, it certainly requires still some modifications with respect to classification of goods and the distance traversed. Of this we will speak later on.

It is true that many difficulties are met with in the application of this system, but it must not therefore be put on one side as impracticable, for it exists and appears to answer very well in a large number of countries, among others in Bavaria on the Ludwig Canal.

It is, however, true that this system demands a deeper acquaintance with the circumstances of navigation, for in its application it would be necessary to examine the bills of lading and at times to check the cargo. Only at places where the statistics of interior navigation are sufficient and where note is taken of the transport effected, an account must be given by the boatman of the quantity of the cargo and the changes it may have undergone in the course of the journey; and here we have at once a ready means of verifying with ease the quantity of the cargo at the time of collecting the dues.

In Germany there exist statistics of traffic on canalised ways, but they are insufficient to fix the traffic per ton and per kilometre. They relate more to loading and discharging, arrival and departure of vessels at the more important points of inland navigation.

The German government has, however, in view a reform which aims at the formation of complete statistics of inland navigation, and propositions worthy of attention have been received from various competent circles, principally from the central committee for the improvement of German river navigation.

A study of the entire question would here lead us too far and it has already been considered at several Congresses.

Besides the possibility of discovering the quantity of the real cargo by means of the data furnished for the statistics of inland navigation there is another method for the same purpose. That is, to require an exact account from the boatman and to establish at the same time a competent control by compelling the boatman to affix to his vessel a certain number of water guages of an obligatory type from which the real cargo could be immediately read off.

I need not here enter further into the purely technical questions of the calculation and the testing of guages, of their correctness in showing the weight of the cargo in proportion to the depth of immersion etc.; some detailed reports on this subject have been published by the Berlin Central Committee for the improvement of inland navigation, which I have added in Annex VII for the use of those interested in the subjet.

It is certain that the real cargo of the vessel can thus be estimated within a few tons, and even exactly, and easily determined if the guages be constructed on a correct and uniform basis.

The declaration of the boatman is thus controlled in the most simple manner; to this may be added another control, certainly less easy and not desirable, viz. the revision of the bills of lading or even the inspection

of the interior of the vessel. We should hesitate long before employing such means of control.

In the first place the intrusion of strangers into private business affairs concerning only the sender and the receiver of the goods is not agreeable to the owner or to any of the parties concerned.

Again, it frequently occurs that the bills of lading are not on board or are not complete, especially at the time of a hurried loading or departure. It is evident that considerable delay would result from these methods of controlling the declaration of the boatman. This method of control cannot be entirely rejected, but could only be exercised in conjunction with measures affording protection to the boatman, such as the requirement of the most scrupulous discretion on the part of the examiners. It will be understood that such control should only be exercised when it is indispensable and, if possible, only in cases where there is a suspicion of fraud.

After what has been said it will be seen that calculation of navigation dues according to the real cargo of the vessel is very possible, although it cannot be denied that there are difficulties in its application. If we now admit the possibility of its application (and the possibility seems to be demonstrated by the example of countries where the system is in force), we must absolutely give it the preference above all other systems for the collection of dues according to the tonnage of the vessel, because all other systems diverge too much from the fundamental idea of a tax imposed as compensation for an economical advantage obtained from the canal.

Nevertheless, it would scarcely be right to maintain the *uniform establishment of this system* on all navigable ways without restriction and the withdrawal of all the others, even though it has been acknowledged as the most equitable and the most practicable one possible. We ought rather on the contrary to retain the principle that, with the exception of systems which are absolutely impracticable, on canals where any other system (such as for instance calculation according to the tonnage of the vessel) is in force, changes should be effected with the greatest circumspection and only when they are in accordance with the wishes of the persons interested. For usually the owners have been for many years accustomed to the system in force and have based on it their tariffs of freights; thus as a general rule the establishment of a new system greatly disturbs their trade and from a material point of view effects rather an aggravation than a decrease of the charges they have to bear.

Following up this principle we may now demand the rejection of insupportable systems, such as the levying of dues according to the value of the goods, which constitutes a tax upon commerce and in practice gives rise to a mass of difficulties.

The question of calculation of dues according to the tonnage of the vessel presents itself in a different light. Even if we admit that this system is

not equitable, that it does not take into account the height of the water, a point so important to boatman, we must not decide on its rejection, except in cases where really great difficulties are presented. We might for instance regard canals the dimensions of which allow to vessels a complete or almost a complete cargo, and many other great difficulties arise when the tax remains the same for small cargoes.

The question of the establishment of a new tax on navigable ways is entirely different. Of all modes of collection the preference may be without hesitation given to the system based on the real cargo.

Thus for example in Prussia, the real cargo is considered as the basis of dues on all the projected ways. For the canal from Dortmund to Emshäfen (unfortunately not yet commenced) and for the Mittelland canal, which will run from the canal from Dortmund to Emshäfen to the central Elbe, mention at least is made of the system in the propositions of interested parties.

2. Consideration of the distance traversed.

All the systems of calculation already mentioned including even the system of calculation on the real cargo are incomplete, so long as the distance traversed, or to be traversed by the vessel on the canal, is not taken into consideration. The question presents many difficulties, especially with regard to collecting offices.

When the collecting offices are placed at different distances from each other along the canal, as is the case on the Marck canals of Prussia, where the dues are collected at a series of locks, each office has to make a complicated calculation of the dues to be collected for the distance traversed by the vessel. The question could be simplified, it is true, by the establishment of fixed and invariable tariffs showing the sum to be paid according to the distance, and for the total distance from one office to another; but this would not suffice, for vessels which had traversed only a part of any of these distances ought not to be required to pay for the total distance, but still they should pay something. The most practical system would without doubt be to collect the toll due for the distance to be traversed as declared by the boatman as soon as the vessel enters the canal, and this declaration is easily controlled. An intermediate office for collection and control on the canal — on the largest canals there may be several offices — could collect the dues imposed on ships which traversed only a distance between two points of the canal and also verify whether passing boats had paid their dues and for what distances.

In order to make sure that a vessel had not traversed more than the distance it had paid for, the staff of officers of the canal would have the right to verify at the times of landing, loading or unloading, the amount of the dues paid.

In this manner and under these conditions the distance traversed would be taken greatly into consideration in the calculation of the dues, even on canalised ways, on which the distance traversed would not otherwise be taken into account and the system of calculation per ton per kilometre would be brought into practice.

If, however, we neglect to include the distance traversed in the canal dues, we meet, especially in the case of canals of great extent, with injustices and difficulties which the owner has been so long accustomed to in some places that he no longer considers them as injustices, but they might very well be dispensed with.

On the other hand for canals of great length we must examine whether the multiplication of the unit of dues by the number of kilometres traversed on the entire length of the canal, or on great parts of the canal, would not give a total relatively too high of dues to be collected, and if in this case, especially where moveable tariffs are in use on rival railways, we should not recur to the system of moveable tariffs.

3. Classification of goods transported.

It is a difficult point to determine whether the classification of goods embarked is useful in the different compilations of dues and up to what point it is practicable. According to the principle we have indicated the justice of such a measure can hardly be contested. From the fundamental principle which we have laid down, that navigation dues should as far as possible correspond with the economical advantage afforded by the canal, the classification of goods in proportion as they bring a higher average freight to the owner is essentially well founded. If the calculation of dues according to value must be acknowledged to be fundamentally wrong, the gradation of dues in different units for goods which bring a higher or a lower freight will not only be equitable, but entirely founded on the same principle.

It is true that principle and practice clash violently in this case, for the collection of dues is rendered difficult by this classification of goods transported and the more difficult in proportion as the classification is more detailed and more exact.

Classification as well as gradation of units of dues both being applied, it would be necessary in order to determine the tax to be paid by a vessel to establish its cargo, not only according to its total tonnage, but according to the different sorts of goods and the tonnage of each of these sorts

Such calculation, however, would be so difficult, tedious, vexatious, and often impracticable for want of knowledge of the real cargo, that the execution of such troublesome work could only cause serious injury to navigation.

Nor can there be any question of a special tariff for *each* sort of goods, for in navigation tariffs there are generally but few gradations, goods of very different kinds and often of very different values being classed in one freight.

On the contrary, in order to arrive at the most just possible tariff of dues, taking into account the highest, the medium, and the lowest units of freight, it is admissible and right to fix a few gradations and to classify goods according to these general groups.

A distinction of this kind is already in practice on many canals in Russia, where raw material (distinctly classified) pays only one half of the dues fixed for other goods.

A classification in three sorts might perhaps be possible:

1st Goods in bales (packages).

2nd Goods in bulk of higher value (for example wheat, sugar, etc.).

3rd Goods in bulk of low value (raw material as coal, stone, ore, dung etc.).

A classification of this kind admits the hypothesis that an examination of the contents of the vessel and a detailed list of the different constituents of the cargo being obviated, the total cargo should be classified and not any part of it, or any part of the goods (according to sort and weight).

This has up to the present time been strictly adhered to in Russia and must be strictly adhered to whenever any alterations in the system occur.

If it were made obligatory to specify the nature of the cargo and to classify distinctly the different sorts of goods according to the different tariffs, navigation would be paralysed and the loss incurred would be much more important than the surplus of dues paid by the owner on account of a part of his cargo being placed on a higher tariff. The only remaming course is to place the cargo in the highest class to which any of its goods belong, when these goods exceed a certain minimum quantity.

If it should be desired to take for the classification of the cargo any other basis than the part which has the greatest weight, recourse would have to be had to an examination of the goods loaded and a calculation of their quantity, whereas according to the system explained above, if there should be any suspicion a glance at the cargo would suffice to determine whether it does or does not exceed the minimum allowed for goods belonging to the higher classification.

A few hundredweight or a few tons on either side would not make any difference. The result of this rapid classification of the total cargo would be that when its heaviest part belongs to one simple class of goods of a higher tariff — the quantity to be admitted without incurring the higher tariff should hardly be more than 50 or a 100 *quintals* (say $2^1/_2$ to 5 tons) — the entire cargo of the vessel would fall under

this same tariff. This difficulty which has been so often pointed out is however inevitable, but as I have said above it is in any case less serious than the injury which would result from a detailed classification of the cargo. We may briefly recapitulate the observations which we have made.

A classification of the cargo of a vessel according to the different sorts of goods without prejudice to navigation is only possible when it is confined to a classification of the total cargo in one of the principal groups: goods in bales (packages), goods in bulk of a higher value, and raw material (goods in bulk of low value). We must entirely refrain from a classification of all the respective constituents of the cargo. If the vessel contains various sorts of goods (for instance, goods in bales and goods in bulk) the dues are fixed on the goods coming under the higher tariff as soon as the total of these goods attains a certain minimum quantity, which is to be determined.

D. Particulars of the calculation of dues on floats.

The dues at present in force for floats are extremely various.

In France, according to the law of 1836 the dues were levied per ten cubic metres (*décastère*). On the present conceded ways the dues are levied partly per trunk, according to the average circumference, and partly per metre in length. In Holland the dues are generally calculated on floats in the block, sometimes per square metre instead of per cubic metre.

In Germany there is great difference between the canal from the Danube to the Maine and the Prussian canals.

On the first, floats pay on the same system as boats, that is per ton per kilometre and the weight is calculated by taking as basis the cubic contents as follows:

Oak and beech wood	14.58 cents per cubic metre
Wood of trees with acicular leaves	2.65 " " "

On the canals of Prussia *the surface* is mostly calculated in square metres.

For instance on the Marck canals it was formerly per $2^1/_2$ square metres for floats of square cut wood and per 3 square metres for all other wood. Now the calculation is per 9 square metres of surface.

On some canals the dues are levied according as the locks are entirely filled or merely to the half or one quarter.

For floats of less dimensions than is generally calculated to fill one quarter of the lock payment is made according to surface.

With these different methods of calculation, implanted in different districts and which often give rise to inconvenience, it is hard to decide which is the best; for besides considerations of principle there are practical considerations to be attentively examined.

According to the principle hitherto admitted of the levying of navigation dues as compensation for an economical advantage offered, float dues should be determined strictly according to the floating quantity.

In a certain measure (as is done on some French canals and the Ludwig Canal in Bavaria) the cubic contents of the float should be taken into consideration and on this the dues should be based. On the other hand observations gathered in practice sufficiently prove that if the cubic calculation be left on one side, it is only the surface of the float, easy to measure and determine, which can be taken as basis for the calculation of the dues.

The distance traversed or to be traversed may be taken into account in the same way as it is for vessels.

The float dues could be paid at the collecting offices according to the tariffs of surface, multiplied by the number of kilometres.

If a want for a gradation of tariffs should be felt, this must of course be arranged in the same way as is done for vessels. On the other hand, as we have said above, we may for practical considerations leave out of account the nature and the weight of the wood.

E. Conclusions on the methods of calculation of dues.

1. Of the existing systems it appears that the system of calculation on the *value of the cargo* cannot be maintained.

Calculation according to the *tonnage of the vessel* in spite of its simplicity from a practical point of view gives rise to difficulties and irregularities on waterways where the height of water may sometimes be unfavourable.

The system of calculation according to the *real cargo* is to be recommended as most corresponding to the character which it is desirable to give to the dues, that is a tax for the economical advantages obtained, and is the most just towards the owners.

The difficulties in its application, which are not small, will disappear by the aid of just measures for the calculation of the cargo and a proper control.

2. When navigable ways which are subject to dues are to be worked this method of calculation according to the real cargo may be recommended as the most just. For navigable ways on which dues are collected according to tonnage we cannot advise a change in the system or the introduction of the method mentioned above, except in the case that difficulties occur and a change is in accordance with the expressed desire of the persons using the waterway.

Generally speaking the greatest prudence should be exercised in making changes in the system of collecting dues, for changes are or might be prejudicial to navigation.

3. In a perfect method of calculation of dues the distance traversed or

to be traversed on the navigable way should also be taken into account and the tariffs should be reckoned par ton per kilometre, including also gradations, if such are rendered necessary by railway competition.

The consideration of the nature of the goods forming the cargo should be circumspect.

Classification without prejudice to navigation is only possible when it is limited to the classification of the total cargo according to certain principal groups, as goods in bales, goods in bulk and raw material.

Any classification of the different goods forming parts of the cargo should be absolutely avoided.

4. Dues on floats are fixed according to the real quantity calculated in cubic metres, or, what is in practice more simple, by the surface measurement. Here too, in the same way as for vessels, the distance traversed should be taken into account, but for practical reasons the nature and the weight of the wood cannot be taken into consideration.

IV. EXEMPTION FROM AND REDUCTION OF DUES. ADDITIONAL DUES.

After the consideration of the principle of the calculation of dues there remain to be discussed the necessary exceptions, and in particular the cases of exemption and reduction. Here as in all cases of public dues the fundamental principle that exceptions be as limited as possible must be insisted upon and only authorised when they are well founded, for example when the refusal of exemption or reduction of dues would give rise to difficulties.

At the present time exemption is allowed on the Prussian canals only to vessels or floats which are the property of the State, or are transporting goods for the account of the State, to fishing boats, boats worked by hand and some other small boats of the same kind. On some canals also to vessels which navigate the canals for the purpose of taking orders, or in consequence of damage received, or for the purpose of affording help to other vessels; in one word, for any other purpose than the transport of goods.

In Holland also exemption is allowed to vessels belonging to the State, as in general to vessels transporting material for public works, and on some canals to vessels transporting fodder and manure.

This last exemption is also allowed on certain canals in Great Britain. The justice of this exemption allowed to vessels belonging to the State and to vessels transporting for the account of the State may be disputed; although for canals belonging to the State it is a question of form, for the State in collecting the dues would merely receive what it was called upon to pay.

The principle of cheapness should be taken into consideration and it should be admitted that the owner of the canal always has the right to favour vessels from which he himself derives advantage; likewise no

objection can be made to exemption being accorded to vessels transporting materials for the use of State works, etc.

The principle here established that dues should be merely a tax for an economical advantage obtained will also justify the clause already mentioned of certain tariffs according to which exemption is allowed to vessels not occupied in the transport of goods, but having other objects (although they may be related to the transport of goods) such as taking orders, collecting information or affording help. etc. For in using the canal for these motives no economical advantage is obtained and therefore navigation dues cannot be claimed in virtue of the principle established.

The case is different if the dues be considered as a compensation for the use of the navigable way.

Exemption and reduction for empty vessels and vessels in ballast require special consideration. It is also a question if empty boats should be entirely free or pay a reduced rate. At first sight and according to the principle of cheapness entire exemption would appear to be the right course; but there is much to be said in favour of a reduced rate.

Apart from the consideration that empty boats use the canal and should therefore pay the dues — which principle has in no way been presented here -- it may be suggested also (considering the dues as compensation for an economical advantage obtained) that the navigation of vessels with the object of seeking a cargo has also its economic value for the merchant.

From a point of view of purely practical opportunity it may also be taken into consideration that the total collection of dues from empty vessels might lead to a small increase of dues on loaded vessels.

The fact that the imposition of dues on empty vessels would fall directly and solely on the captain who had not been able to find a return freight and was therefore obliged to return empty, speaks in favour of complete exemption from dues for empty vessels. The navigation of empty vessels does not *per se* produce any economical advantage and the principle of the levying of dues for the simple use of the navigable way is not admissible. In the tariffs in force this point is regulated in very various ways. In France the dues are greatly reduced. In Holland empty boats are sometimes free and sometimes pay half the dues or enjoy a large reduction. In Prussia up to quite lately it was nearly always one sixth of the tariff and according to the latest regulations still less. On the Bavarian Ludwig canal (from the Danube to the Maine) fixed reduced tariffs, according to different classes, are established for such vessels.

In some canal tariffs there exist besides reductions for vessels which traverse the *entire* length of the canal and those which make a *regular* use of the canal or some part of it. But these reductions are only admissible in so far as the advantages afforded to persons using the canal have regard to the competition presented to the canal by railways or rival canals.

No great importance can be attached to them, for these conditions are

rarely presented, and it is not admissible that this reduction (small as it may be) should be allowed to influence in any way whatever the traffic on the canal. There is another and more important point to be discussed, namely, whether reductions in favour of vessels of extraordinarily large dimensions or, on the contrary, in favour of those of small dimensions should be declared equitable or otherwise. An example of the first method was in existence until six months ago on the Marck canals — it is now abolished — according to which dues were only collected on a certain relatively moderate maximum of 116 tons (at the present day these canals are used by vessels of 400 tons). And in this way larger vessels had to pay a comparatively very reduced rate, sometimes only a third or still less of the sum they would have to pay if charged at their full tonnage.

The inequality resulting from this method of charges to the small owners often caused great difficulties, and at last a reform was decided upon which, however, did not really relieve the small owners, but only placed a much higher tax on large vessels by the elevation of the maximum taken as the unit. (Figures relating to this elevation will be found in the report of the Central Committee for the improvement of fluvial ways in Germany. See Annex IV.)

But even if a tax of this kind really imposed a more heavy burden on small vessels, and on the other hand there was no serious motive for favouring large vessels, this measure must nevertheless not be considered as unfounded.

Another question, which we will not further examine here, is whether, in view of this large increase imposed suddenly on large vessels, it would not have been preferable to have recourse to a reduction of the units of dues rather than to an elevation of them. Favour should not be accorded to large any more than to small vessels.

Even if it were desirable for social or political considerations to favour, by reductions of this nature, the small owner who is too heavily burdened, it must be acknowledged that the classification presents difficulties; for frequently these small owners carry on the transport for large owners and navigation companies, so that these only would be benefited. Finally, too numerous reductions would lead or might lead to an elevation of the units of dues in cases where the collection of dues must produce a fixed total.

There remains to be considered the question of secondary dues in addition to the general dues for navigation on fluvial ways.

At the commencement of our work we rejected this.

From the point of view of the principle of a compensation for an economical advantage obtained from the use of the canal, these secondary dues, which at the present day are often applied, should be avoided, even when the service established on the canal, such as locks, lifting of

boats, working of bridges etc. are the cause of expense to the owner of the canal.

Only a very few special tolls should be admitted, such as for the use of locks etc. *during the night*, for this service would only be demanded by the vessel when the extra speed which it would obtain would bring an extra profit. On the same principle are founded dues collected for privileges on locks, as for example on the navigable ways in Prussia.

We will sum up the conclusions on exemption from and reduction of dues and on secondary impositions in addition to the general dues.

1st The exemption from and the reduction of dues should be limited as much as possible. Exemption accorded to vessels not occupied in the transport of goods — as is allowed by some tariffs for certain cases — is legitimate and ought to be maintained. Empty boats should be exempt from dues, or be but moderately taxed when their object is partly to seek for transport.

2nd In general all other reductions and favours to vessels carrying goods, whether it be the fixing of a maximum for large vessels, or special reductions for small vessels, should be avoided. As far as possible the placing on an equality of all vessels carrying goods is the most just principle.

3rd The collection of special tolls for opening locks, raising vessels, working of bridges etc. is contrary to the principle of compensation for the general use of navigable ways. Still a certain moderate due may be levied for the working of plant during the night; a right of privilege in locks should also be specially taxed.

V. COLLECTION OF DUES. CONTROL.

I may be allowed to make a few brief remarks on this subject, a detailed report being more in the province of those gentlemen who have for years made a study of these purely practical points. The collection of dues must be, and will be, different according as the calculation is made at the collection office with or without consideration of the distance traversed. In the second case — as is now almost generally the practice — the dues should be paid according to the tariffs at certain points of the canal, generally at the most important locks, which are practically suitable for the purpose, on account of the continual presence of employés, the necessity for stopping, etc. In the first case certain changes would be necessary.

At the beginning and at the end of the canal collecting offices should be established, and on longer canals also one or more offices in the course of their length. A suitable point is just before or past a lock. At the first collecting office the owner should pay in advance the dues for all the distance which he proposes to traverse.

The collecting offices would only have to control the payment. The collecting office where the boatman pays the dues should give him a receipt in the form either of a list which can be easily and rapidly filled in or by suitably stamping the bills of lading.

Besides the control at the offices, another should be established at the places where vessels discharge between two collecting offices and should be confided with proper instructions to the harbour masters, inspectors or other functionaries of the canal, who will see that no farther distance has been traversed than that for which dues have been paid.

The dues according to the distance from the collecting office to the place of destination should be established in tables, so as to simplify the calculation and allow it to be rapidly made.

The control of the real cargo should be made by functionaries who are always present at the place of collection. Any claims or difficulties which might arise could be cleared up later on.

If, on account of damages, the sale of cargo, orders to return, or any similar reason the entire distance to the place of destination be not traversed, a claim for reimbursement should be made at the first opportunity.

Translated by G. J. Rowland, Amsterdam.

Annexes I to VII.

Annex I.

REVIEW

of the artificial navigable ways in Prussia, for the use of which dues are collected for the account of the State; of the sums devoted to their repair, essential improvement and enlargement, to the technical service, the regular maintenance and the collection of tolls, according to the average drawn from the State budget for the period 1889 to 1890/91;

as also of the amount of the dues collected according to the average figures of the same period.

N°.	CANAL.	Length in km.	Number of locks.	EXPENSES FOR REPAIRS, ESSENTIAL IMPROVEMENT AND ENLARGEMENT.
I.	II.	III.	IV.	V.
1.	Canal between Memel and Pegel by way of the canalised Gilge, the Seckenburg canal, the great Frederic fosses and the Deime.	104		For essential improvement and extension. The expense for repairs has not yet been determined. As regards the great Frederic fosses, which were established from 1688 to 1696 by the Count of Waldburg, they were acquired by the Government in accordance with a decree given at Charlottenburg the 29th of August 1709 for the sum of 60 000 thalers.
2.	Oberland-canal. Navigable way between the Oberland lakes and Elbing including the Schilling—Drewenz canals.	134	4 locks and 5 inclined planes.	
3.	Vistula Haff canal.	20	2	
4.	Uecker canal.	0.325		
5.	The canalised Upper Netze.	105	8	
6.	The Bromberg canal with the Brahe and the lower Netze.	55	14	
7.	Klodnitz canal.	46	18	For repairs 2392134 M. „ essential improvement and enlargement 665857.67 „ The expense of the works commenced in 1889/90 for putting this canal in order is estimated at 1120000 M.
8.	The Oder from Cosel to Breslau including the entrance to the Oppeln harbour (Mühlgraben locks.)	157	6	

Capital in marks. VI.	Interest on Capital at $3^1/_2$ % in marks. VII.	Expense of technical service, ordinary maintenance and collection of dues, in marks. VIII.	Total of the sums of columns VII and VIII in marks. IX.	Amount of dues received in marks. X.	REMARKS. XI.
1937850	67825	52786	120611	45911	Deficit 74700 M. „ against column VIII 6875 M.
5735500	200743	120798	321541	9012	Deficit 312529 M. „ against column VIII 111786 M.
1079000	37765	36429	74194	30988	Deficit 43206 M. „ against column VIII 5441 M.
60736	2126	3156	5282	12680	Profit 7408 M. In consequence of this a reduction of dues was made by the tariff of July 25th 1892.
3626522	126928	59750	186678	4597	Deficit 182081 M. „ against column VIII 55153 M.
2512611	87941	140397	228338	112898	Deficit 115440 M. „ against column VIII 27499 M.
3057992	107030	32301	139331	3700	Deficit 135631 M. „ against column VIII 28607 M. On account of the interruption to traffic caused by the repairs of 1889/90 and 1890/91 figures corresponding to the years 1886/87 and 1887/88 are taken as a basis.
1980668	69323	19554	88877	12997	Deficit 75880 M. „ against column VIII 6557 M.

N°.	CANAL.	Length in km.	Number of locks.	EXPENSES FOR REPAIRS, ESSENTIAL IMPROVEMENT AND ENLARGEMENT.	
I.	II.	III.	IV.	V.	
9.	The Marck canals (between the Oder and the Elbe) as follows:	1003	84		
	1. The interior dike canal.	10.5	2		7122488 M
	2. The Louisenstadt canal.	2.2	1		2501762 „
	3. The Spree-canal (Kupfer fosses.)	2	1	Expense of repairing locks, remainder unknown.	159633 „
	4. Canal from Berlin to Spandau.	8.3	2	Expense of repairing one lock 403221 M., for deepening and widening in the years 1889/90 and 1890/91 160000 M. together remainder unknown.	563221 „
	5. Canal between the Spree and the canal from Berlin to Spandau.	3.2		Unknown.	
	6. The Spree from Leibsch to its junction with the Havel.	176	3	Repairs to the Cossenblatt locks 122000 M., Charlottenburg locks 680000 M. and Expense of deepening and enlarging the lower Spree 1751000 M. together rest unknown.	2553000 „
	7. The Havel with the Voss canal from the Mecklenburg frontier to the Liebenwald.	61	7		2248000 „
	8. The Templin canal.	23.2	3	Expense of repairing the 3 locks	270000
	9. The navigable way from Liebenwald to Hohensaaten (Finow canal.)	55.6	14	Expense of canal unknown. For locks 6180000 M., for enlargement and improvement during the last 15 years 3535000 M. together	9715000
	10. Malzer canal and the regulated Havel to Spandau.	47.3	4	Expense of canal unknown. Expense of locks	1617000

Capital n marks.	Interest on Capital at $3^1/_2$ % in marks.	Expense of technical service, ordinary maintenance and collection of dues, in marks.	Total of the sums of columns VII and VIII in marks.	Amount of dues received in marks.	REMARKS.
VI.	VII.	VIII.	IX.	X.	XI.
55379566	1938284	873285	2811569	887556	Deficit 1924013 M. Profit against column VIII 14271 M. In consequence of the increase of tariff in the financial year 1892/93 the amount of the dues for 1893/94 is estimated at 1017758 M. Taking this amount as basis we find a Deficit of 1793811 M. and the Profit against column VIII 144473 m. if the amount of expenses has not increased, and this cannot be immediately established.

N°.	CANAL.	Length in km.	Number of locks.	EXPENSES FOR REPAIRS, ESSENTIAL IMPROVEMENT AND ENLARGEMENT.	
I.	II.	III.	IV.	V.	
(9)	11. Verbillin canal.	11	2		453000 M
	12. The regulated Havel from Spandau to the Elbe including the Sacrow-Paretz canal and the Brandenburg lock canal.	181	3	In the last 10 years for the improvement of the Havel 200000 M. Rest unknown. For the Sacrow-Paretz canal and the locks 2101000 M. together	4101000 „
	13. Niederneuendorf canal.	15.2	2	For the canal unknown. For the locks	125000 „
	14. Rheinsberg-Zechlin canal.	21.5	1		804000 „
	15. Lychener canal.	9	1	Expense of canal unknown. Improvement of same 17000 M. For the locks 90000 M. together	107000 „
	16. Wentow canal.	11.6	1	For the locks 70000 M. For the establishment of the canal unknown. For improvement 6900 M. together	76900 „
	17. Ruppiner canal and the Rhine waterway.	66.5	5	For the canal unknown For the locks	592000 „
	18. Fehrbellin canal and the Schwarzer fosses.	17	3		196620 „
	19. The regulated Dosse.	17	1		4000 „
	20. Rüdersdorf waters.	9	1	For the canal unknown. For the locks	436000 „
	21. The Dahme.	39.5	2	For the canal unknown. For the locks	215000 „
	22. Storkow canal.	23	3	For the canal unknown. For the locks	297000 „
	23. The Oder-Spree canal.	100.6	8		12825000 „
	24. The Friedrich-Wilhelm canal.	27	8	For the canal unknown. For the locks	1030000 „
	25. The Old Plauer canal (Parey canal) and the new Plauer canal (Ihle canal).	64.6	6	Expense of establishment of old canal unknown. For the establishment of the new canal and the improvement of both canals	7366942 „
				General total . .	55379566 M

Capital n marks.	Interest on Capital at $3^1/_2$ % in marks.	Expense of technical service, ordinary maintenance and collection of dues, in marks.	Total of the sums of columns VII and VIII in marks.	Amount of dues received in marks.	Remarks.
VI.	VII.	VIII.	IX.	X.	XI.

N°. I.	CANAL II.	Length in km. III.	Number of locks. IV.	EXPENSES FOR REPAIRS, IMPROVEMENT AND ENLARGEMENT. V.
10.	The Saale and the Unstrut.	241	29	For the locks at Halle and Alsleben Rest unknown.
11.	Haale Aue with the Bastenberg lock.	7	1	Unknown
12.	The Treene with the lock at Friedrichstadt.	22	1	For the locks and draw-bridges.
13.	Ernst August canal with the lock at Wilhelmsburg (Elbe).	2.5	1	
14.	The river Schwinge with the Salzthor lock at Stade.	6.2	1	
15.	Fangstaken fosses near Osterholz.		4	Expense of establishment unknown For improvement 6218 M.
16.	Hamme-Oste canal with the lock at Bremerförde.	16	1	
17.	Bederkesa-Geste canal with the lock at Bederkesa.	11.4	1	
18.	Georgsfehn canals. a. Georgfehn canal. b. North Georgfehn canal. c. South Georgfehn canal.	17.3	4	
19.	Sielmönker deep.	7		Expense of establishment unknown For improvement in 1886 10000 M.
20.	Spoy canal.	10	1	

Capital in marks.	Interest on Capital at $3^1/_2$ % in marks.	Expense of technical service, ordinary maintenance and collection of dues, in marks.	Total of the sums of columns VII and VIII in marks.	Amount of dues received in marks.	REMARKS.
VI.	VII.	VIII.	IX.	X.	XI.
634341	22202	13977	36179	30064	Deficit 6115 M. Profit against column VIII 16087 M.
		900	900	147	Deficit 753 M.
360000	12600	1203	13803	1066	Deficit 12737 M. „ against column VIII 137 M.
140000	4900	4773	9673	957	Deficit 8716 M. „ against column VIII 3816 M.
167565	5865	1656	7521	1596	Deficit 5925 M. „ against column VIII 60 M.
6218	218	33	251	18	Deficit 233 M. „ against column VIII 15 M.
55000	1925	1344	3269	2306	Deficit 963 M. Profit against column VIII 962 M.
518000	18130	4550	22680	437	Deficit 22243 M. „ against column VIII 4113 M.
363000	12705	274	12979	76	Deficit 12903 M. „ against column VIII 198 M.
10000	350		350	900	Profit 550 M. The profit represents interest on a capital of 15914 M., which would not cover the unknown expense of establishment.
439359	15378	8000	23378	3093	Deficit 20285 M. „ against column VIII 4907 M.
78063928	2732238	1375166	4107404	1160999	Deficit 2946405 M. „ against column VIII 214167 M.

Annex II.

FULLY LADI

100	6	—	3	—
105	6	30	3	15
110	6	60	3	30
115	6	90	3	45
$116^2/_3$	7	—	3	50
over $116^2/_3$	not taken into account			

ount. Pf.	Tonnage in tons up to.	Amount. M.	Pf.	Tonnage in tons up to.	With full cargo. M	
15	5		5	5	—	
30	10	—	10	10	—	
45	15	—	15	15	—	
60	20	—	20	20	—	
75	25	—	25	25	—	
90	30	—	30	30	—	
05	35	—	35	35	—	
20	40	—	40	40	—	
35	45	—	45	45	—	68
50	50	—	50	50	—	75
65	55	—	55	55	—	83
80	60	—	60	60	—	90
95	65	—	65	65	—	98
—	70	—	70	70	1	05
taken	75	—	75	75	1	13
account.	80	—	80	80	1	20
	85	—	85	85	1	28
	90	—	90	90	1	35
	95	—	95	95	1	43
	100	1	—	100	1	50
	105	1	05	105	1	58
	110	1	10	110	1	65
	115	1	15	115	1	73
	120	1	20	$116^2/_3$	1	75
	over 120	not taken into account.		over $116^2/_3$	not taken into accoun	

Observation. The basis of dues for vessels taxed in *Hamburg* or *Anstalt* is the declare table.

Annex I.

REVIEW

of the artificial navigable ways in Prussia, for the use of which dues are collected for the account of the State; of the sums devoted to their repair, essential improvement and enlargement, to the technical service, the regular maintenance and the collection of tolls, according to the average drawn from the State budget for the period 1889 to 1890/91;

as also of the amount of the dues collected according to the average figures of the same period.

Annex III.

TARIFF

for the collection of navigation dues on the Uecker canal near Ueckermunde.

Canal dues are fixed:

I. For sea-going vessels:

a, with cargo:

on entering	3 pf.
on leaving	3 „

b, in ballast or empty

on entering	1 „
on leaving	1 „

for every two or part of two cubic metres capacity.

II. For river boats, at least when carrying cargo, either on entering or leaving the canal: for entering and leaving together 5 pf. for every 2000 or part of 2000 kilogrammes burden

III. For tow-boats without reference to their tonnage 25 pf. for entering and leaving together for each vessel.

IV. At night (one hour after sunset until one hour before sunrise) an additional toll of 30 pf. for each vessel.

Exceptions.

1. Vessels of which the amount of the cargo does not exceed one fourth of their capacity are considered as in ballast.

2. For tow-boats the choice is left open instead of paying toll for each journey according to the tariff, to pay a yearly subscription, the amount of which is fixed by the administration according to the circumstances of the case.

Exemptions.

Exemption from canal dues both on entering and leaving is accorded to:

1. Vessels navigating the canal only for the purpose of procuring information or taking orders and those leaving the canal without taking in or discharging cargo.

2. Vessels which put into the canal on account of damage suffered or other difficulties, as ice, storm or contrary winds, and leave again without discharging or taking in any part of their cargo.

3. Vessels which leave or enter the canal for the purpose of affording aid to vessels stranded or in distress. If in this case the vessel affording

aid be employed in discharging stranded goods, it is only exempted when the partly unloaded or lightened vessel uses the canal for the purpose of again embarking the goods or for entirely discharging.

4. Vessels which
   a, are Royal property, or the property of the German Empire or of the Kingdom of Prussia, or
   b, without any other cargo but objects for royalty, the State or the Kingdom, or leave the canal empty, either with the sole purpose of transporting such objects, or after having discharged such exclusively.

5. River vessels which enter the canal empty or in ballast and leave again without taking cargo.

6. Boats belonging to ships and all vessels of not more than twelve cubic metres capacity.

7. All vessels which are entirely used for fishing purposes with the exception of tow-boats.

Additional regulations.

1. The capacity of the vessel is, according to the regulations of July the 5th 1872 and of June the 20th 1888 respecting ship measurements, to be understood as the average net capacity. In cases where for the application of the tariff it may be necessary to resolve the cargo into capacity, 500 kilogrammes are to be taken as equivalent to one cubic metre capacity.

2. The canal dues including the additional tolls both for entering and leaving are collected by the office at Ueckermünde.

Stettin, July the 25th 1892.

The provincial director of dues
L. S as representative
(signed) Herrosé.

ADDENDUM.

By virtue of special authority granted to me on the 2nd of May of this year — III 5221 — by the Minister of Finance and approved by the Minister of Public Works, the following additional exemption from dues for the navigation of the Uecker canal is granted:

Vessels which only visit the canal as a refuge in distress and are in the interest of safety directed by the inspector to lay to at a place inside the bar are exempt from the additional night due (IV) on entrance as well as on departure, provided the latter takes place the same night.

Stettin, June the 7th 1893.

The provincial director of dues
as representative,
(signed) Herrosé.

Annex IV.

TARIFF

for the collection of dues for the navigation of the canals between the Oder and the Elbe.

Dated December the 27th 1871.

(*With the changes made by the order of August* 1892.)

A. From every vessel each time that it passes any one of the following collecting offices (locks):

on the Finow canal at Liebenwalde or Neustadt-Eberswalde,
on the Friedrich-Wilhelms canal at Neuhaus or Brieskow,
on the Spree at Cossenblatt, Fürstenwalde or Berlin,
on the Havel at Zaarenschleuse, Zehdenick, Oranienburg, Spandau, Brandenburg or Rathenow,
on the Ruppin canal at the Theirgarten lock near Oranienburg,
on the Templin canal on the Kannenburg lock,
on the Plauer canal at Parey or at Plaue, at each office 40 pf. (1) *for every* 5000 *kilogrammes or five tons tonnage is levied.*

Less amounts than 5000 kilogrammes are counted as 5000 kilogrammes.

Exceptions.

1. Vessels loaded entirely with the following material pay only one half of the dues noted under A:

Fuel (as wood, turf, coal, coke), boards up to a length of one metre etc.; fodder, rushes, reeds, sea-grass, faggots, planks, bark, tan, tiles, drain-pipes, granite stone, plaster and cement, milled fire-lime and gypsum stone (including rough works in same); with earth sand, clay, earthenware, gravel, heavy timber, pig and cast-iron, brick-dust or gypseous earth, milled stone, lime or cement; with broken glass, loam, ashes, iron ore; or with manure as dung, marl, gypsum, lime, refuse

(1) Fomerly 30 pf.

from sugar refineries, bones etc.; with salt, Glauber's salts, saltpetre, soda, potash, waste salts; with empty casks, cases, baskets or sacks (1).

2. Vessels which, apart from their rigging, food for the crew and certain indispensable objects, such as bords and tubs, do not carry more than 300 kilogrammes and provided they do not carry passengers, pay only one pfennig for every five tons or part of five tons tonnage.

The same reduction is made to vessels which only serve as lighters.

Observations on 1 *and* 2. If the cargo consits partly of the class mentioned under 1 and partly of other objects, or if it be used for carrying passengers, full dues are charged.

B. Timber floats each time they pass any one of the offices named under A pay as follows:

I. 1. Floats consisting wholly or partly of square cut wood or beams 16 pfennigs (formerly 12) *for every* 9 *square metres of surface* including the propelling apparatus.

2. All other floats 13 pfennigs (formerly 18) *for every* 9 *square metres of surface* including the propelling apparatus.

In calculating surface, an area of less than 9 square metres is charged as 9 full square metres, while an excess of less than $4^1/_2$ square metres is left out of account, and an excess of $4^1/_2$ square metres or more is counted as 9 square metres.

II. If the floating wood is loaded with staves or felly wood or with objects named under list 1 of exceptions under A, no further dues are charged except those quoted under B, 1.

III. If the float, apart from the rigging and provisions for the crew, carries other objects such as staves or felly wood, or such as the exceptions under A 1, of more than a weight of 300 kilogrammes, it has to pay a due of *five silbergroschen* at every office in addition to the dues noted under B, 1.

Observation. When the float consists of several parts each loaded part coming under B III is treated as a separate float.

Exemptions.

Dues are not levied on:

1. Vessels or floats belonging to the State or transporting for the State on production of a pass.

(1) But in no case is a higher due levied than a total of one thaler and five silbergroschen (350 pf.). (Since 1875 : 700 pf.)

2. Fishing boats, pleasure boats, dingeys, rowing boats and such small craft which according to the nature of their build do not carry cargo, when they do not require any special lock service, if they give notice of their intended journey at the first lock passed.

3. Vessels and floats leaving the Landwehr and the Louisestadt canals at Berlin when the dues have been paid on entering.

Addional regulations.

1. Dues are to be paid by the master of the vessel or float at the appointed collecting office before entering the lock unless the payment has been arranged beforehand.

2. The Minister of Finance shall decide on the places at which payment is to be made, where and in what way the tonnage of the vessel, nature of the cargo, and exemptions to be allowed are to be determined.

3. According to the rules under N° 10 of the tariff for the Plauer canal, dated November the 14th 1824 (parliamentary records S 220), and under N° 4 of the additional rules for tariffs on the canals, between the Oder and the Elbe dated June the 18th 1828 (parliamentary records S 110).

Annex V.

TARIFF

for the collection of dues on the Ladurig canal.

SPECIAL RULES.

A. Navigation dues.

1) Loaded vessels per *Sporro-Zollcenter* (50 kilogrammes) per kilometre traversed:

I. Class 0.05775 pfennigs.

a) Fuel, as:

Firewood,	Peat,
Charcoal,	Coal,
Turf,	Coke,
Tan-cake,	

b) Building materials, as:

Loam,	Mortar,
Marl,	Drain pipes,
Sand,	Worked and unworked stone,
Gravel,	Quarry and plaster stone,
Potters clay,	Building wood and cabinet wood,
Gypsum,	Wood from local saw mills, as:
Lime,	
Cement,	Boards
Slates, tiles and bricks,	Planks and laths.

c. Lead, iron and copper ore:

Spar,	Wrought-iron,
Peat,	Iron-filings and forge scales.
Litharge,	Graphite,
Pig-iron,	Black lead,

d) Refuse and manure as:

Ashes,	Bone manure,
Guano,	Poudrette,
Lime,	Phosphorates,
Bones,	Gypseons soda,
Powdered bones,	Sugar refuse.

---

(1) To this belong the principal objects named above.

II. Class 0.077 pfennigs.

All goods not mentioned in the first class.

2) Empty vessels pay per kilometre as follows:

Vessels of the 1st class	7.70 pfennigs.
" " " 2nd "	6.16 "
" " " 3rd "	3.85 "
" " " 4th "	3.08 "
" " " 5th "	1.92 "
" " " 6th "	1.54 "

A loaded vessel for which the canal dues would not be so high as if it were charged in its class as empty, is charged as empty.

3) The weight of the cargo is determined from the guages of the vessel with the aid of the bills of lading and other available indications.

By mixed cargoes some goods must be weighed if the proportion of weight cannot be determined from the tariffs.

5) A reduction of dues to as much as 10 % is allowed to vessels doing a regular service.

A reduction of 10 % is also allowed to:

a) All vessels (not doing a regular service) loaded and with bills of lading direct from the Rhine, which travel the whole length of the canal.

b) Vessels loaded with wood and planks entering from the Danube and travelling the whole length.

c) All other goods coming by ship from the Danube and using the canal at least as far as Neumarkt.

6) Dues on floats and their burdens are arranged according to the above tariffs, the weight being calculated on the cubic measurement as follows:

Oak and beech wood	14.58 cwt. per cubic metre.
Pine and other timber	9.65 " " " "

Annex VI.

Review of the navigation dues in force on the Marck Canals since September the 1st 1892 compared with those previously in force.

(A report of the Central Comittee of Berlin for the improvement of fluvial navigation dated December 1892).

	On vessels of 400 tons is charged for navigation dues for every ton of cargo:					
	1. At high water fully laden		2. At mean water level $^2/_3$ cargo		3. At low water $^1/_3$ cargo	
	I. Cl. *Pf.*	II. Cl. *Pf.*	I. Cl. *Pf.*	II. Cl. *Pf.*	I. Cl. *Pf.*	II. Cl. *Pf.*
1. From Breslau to Hamburg or to Magdeburg and vice versa through the Oder-Spree or Plauer canal there are 7 tolls to be paid, namely in Fürstenberg, Kersdorf, Fürstenwald, Wernsdorf, Berlin and Brandenburg for the Breslau-Hamburg way and on the five first named locks and those at Plaue and Niegripp for the Breslau-Magdeburg waterway. Latterly (since Sept. 1st 1892) a vessel of 400 t. has to pay for goods I. Cl. 7 × 32 M. = 224 M., for goods II. Cl. 7 × 16 M. = 112 M., for each ton of cargo	56.—	28.—	84.—	42.—	168.—	84.—
against formerly I. Cl. 7 × 7 M. = 49 M., II. Cl. 7 × 3.50 M. = 24.50 M., thus for each ton of cargo	12.25	6.13	18.37	9.30	36.75	18.37
therefore an increase on each ton of	43.75	21.87	65.63	32.70	131.25	65.63
2. From Breslau to Berlin and vice versa using the Berlin town lock and the Oder-Spree Canal there are 5 locks (Fürstenberg, Kersdorf, Fürstenwald, Wernsdorf, Berlin), since Sept. 1st 1892 they charge for a vessel of 400 tons						

for goods I. Cl. 5 × 32 M. = 160 M., for goods II. Cl. 5 × 16 = 80 M., thus for each ton of cargo	40.—	20.—	60.—	30.—	120.—	60.—
against previously I. Cl. 5 × 7 M. = 35 M., for II. Cl. 5 × 3.50 M = 17.50 M., thus for every ton of cargo	8.75	4.37	13.12	6.56	26.25	13.12
therefore an increase on each ton of	31.25	15.63	46.88	23.44	93.75	46.88
3. From Breslau to Berlin and vice versa without using the Berlin town locks there are 5 tolls to be paid. Since Sept. 1st 1892 these are for vessels of 400 tons						
for goods of I. Cl. 4 × 32 M., = 128 M., for goods II. Cl. 4 × 16 M. = 64 M., thus for each ton of cargo	32.—	16.—	48.—	24.—	96.—	48.—
against formerly I. Cl. 4 × 7 M. = 28 M., II. Cl. 4 × 350 M. = 14 M., thus for each ton of cargo	7.—	3.50	10.50	5.25	21.—	10.50
therefore an increase on each ton of cargo of	25.—	12.50	37.50	18.75	75.—	37.50
4. From Hamburg to Berlin and vice versa, using the Berlin town lock there are 3 tolls to be paid (Rathenow, Brandenburg, Berlin), since Sept. 1st 1892 the amounts of the same for vessels of 400 tons,						
for goods 1 Cl. 3 × 32 M. = 96 M., for goods 11 Cl. 3 × 16 M. = 48 M., thus for each ton of cargo	24.—	12.—	36.—	18.—	72.—	36.—
against previously I. Cl. 3 × 7 M. = 21 M., II Cl. 3.50 M. = 10.50 M., thus for each ton of cargo	5.25	2.625	7.88	3.94	15.76	7.88
therefore an increase on each ton of cargo of	18.75	9.375	28.12	14.06	56.24	28.12
5. As said above there are 2 tolls to be paid without the use of the Berlin town lock, namely since Sept. 1st 1892 for a vessel of 400 tons						
for I Cl. goods 2 × 32 M. = 64 M., II Cl. 2 × 16 M. = 32 M., thus for each ton of cargo	16.—	8.—	24.—	12.—	48.—	24.—
against previously I. Cl. 2 × 7 M. = 14 M., II. Cl. 2 × 3.50 = 7 M., thus for each ton of cargo	3.50	1.75	5.25	2.625	10.50	5.25
therefore an increase on each ton of	12.50	6.25	18.75	9.375	37.50	18.75

	On vessels of 400 tons is charged for navigation dues for every ton of cargo:					
	1. At high water fully laden		2. At mean water level $^2/_3$ cargo		3. At low water $^1/_3$ cargo	
	I. Cl. *Pf.*	II. Cl. *Pf.*	I. Cl. *Pf.*	II. Cl. *Pf.*	I. Cl. *Pf.*	II. Cl. *Pf.*
6. From Magdeburg to Berlin using the Berlin town lock or vice versa there are 4 tolls to be paid (Niegripp, Plaue, Brandenburg, Berlin). They are since Sept. 1st 1892 for vessels of 400 tons						
for I. Cl. goods 4 × 32 M. = 128 M., for II. Cl. 4 × 16 M. = 64 M., thus for each ton of cargo	32.—	16.—	48.—	24.—	96.—	48.—
against previously I. Cl. 4 × 7 = 28 M., II Cl. 4 × 3.50 = 14 M., thus for each ton of cargo	7.—	3.50	10.50	5.25	21.—	10.50
therefore an increase on each ton of cargo of	25.—	12.50	37.50	18.75	75.—	37.50
7. As above, but without using the Berlin town lock, there are 3 tolls to be paid. They are since Sept. 1st 1892 for vessels of 400 tons,						
for I. Cl. goods 3 × 32 M. = 96 M., II. Cl. 3 × 16 M. = 48 M., thus for each ton of cargo	24.—	12.—	36.—	18.—	72.—	36.—
against previously I. Cl. 3 × 7 M. = 21 M., II. Cl. 3 × 3.50 M. = 10.50 M., thus for each ton of cargo	5.25	2.625	7.88	3.94	15.76	7.88
therefore an increase on each ton of cargo of	18.75	9.375	28.12	14.06	56.24	28.12
8. From Stettin to Hamburg or vice versa there are 6 tolls to be paid (Eberswald, Liebenwald, Oranienburg, Spandau, Brandenburg and Rathenow). They are since Sept. 1st 1892, for vessels of 170 tons						
for goods of I. Cl. 6 × 13.60 M. = 81.60 M. II Cl. 6 × 6.80 M. = 40.80 M., thus for each ton of cargo	48.—	24.—	72.—	36.—	144.—	72.—
against previously I. Cl. 6 × 7 M. = 42 M. II. Cl. 6 × 3.50 M. = 21 M., thus for each ton of cargo	24.70	12.35	47.05	23.525	94.10	47.05
therefore an increase on each ton of cargo of	[illegible]	[illegible]	[illegible]	[illegible]	49.90	[illegible]

there are 5 tolls to be paid (Eberswald, Liebenwald, Oranienburg, Spandau or Plötzensee and Berlin). They are since Sept. 1st 1892 for vessels of 170 tons						
for goods of I. Cl. 5 × 13.60 M. = 68 M., II. Cl. 5 × 6.80 M. = 34 M., thus for each ton of cargo	40.—	20.—	60.—	30.—	120.—	60.—
against previously I. Cl. 5 × 7 M. = 35 M., II. Cl. 5 × 3.50 M. = 17.50 M., thus for each ton of cargo	20.59	10.29	30.88	15.44	61.76	30.88
therefore an increase on each ton of cargo of	19.41	9.71	29.12	14.56	58.84	29.12
10. As above, but without using the Berlin town lock there are 4 tolls to be paid. They are since Sept. 1st 1892 for vessels of 170 tons						
for goods I. Cl. 4 × 13.60 M. = 54.40 M., II. Cl. 4 × 6.80 M. = 27.20 M., thus for each ton of cargo	32.—	16.—	48.—	24.—	96.—	48.—
against previonsly I. Cl. 4 × 7 M. = 28 M., II. Cl. 4 × 3.50 M. = 14 M., thus for each ton of cargo	16.47	8.235	24.705	12.45	49.41	24.705
therefore an increase on each ton of cargo of	15.53	7.765	23.295	11.65	46.59	23.295
11. From Stettin to Magdeburg or vice versa there are 7 locks to be paid (Eberswald, Liebenwald, Oranienburg, Spandau, Brandenburg, Plaue and Niegripp). They are since Sept. 1st 1892 for vessels of 170 tons						
for goods I. Cl. 7 × 13.60 M. = 95.20 M., II. Cl. 7 × 6.80 M. = 47.60 M., thus for each ton of cargo	56.—	28.—	84.—	42.—	168.—	84.—
against previously I. Cl. 7 × 7 M. = 49 M., II. Cl. 7 × 3.50 M. = 24.50 M., thus for each ton of cargo	28.—	14.412	43.235	21.618	86.47	43.235
therefore an increase on each ton of cargo of	27.177	13.588	40.765	20.382	81.653	40.765

Annex VII.

Report of the Central Committee of Berlin for the improvement of Inland Navigation in Germany.

On ship measurement and water-guage.

(*Extract from a report to the Congress of December* 1892).

---

1) If canal dues are to be calculated, not as up to the present according to the tonnage, but in future according to the weight of the cargo, the calculation of the capacity and the application of a guage is necessary.

2) The guage should be fixed to the side of the vessel just above the water-line. It is to be recommended that the guage should be so divided that the weight of the cargo can be immediately read off for every or 10 tons.

3) It is advisable that the guage should be in connection with an immersion guage divided in degrees of ten metres, from which the depth of immersion can be immediately read oft. The greatest admissible depth of immersion should be plainly indicated in this guage.

4) The guage can be most easily checked and corrected if the measurement of the vessel is arranged according to the proposals of the Commission on interior measurements of vessels, as contained in the report of the Central Committee of June the 18th 1888.

If in this calculation the surface area of the upper, middle and lower sections (*Eo*, *Em* and *Eu*) be fixed with regard to the tonnage, we may for a vessel, which is more than half loaded, use the following formula:

$$\triangle = \frac{Eo + Em}{200} (y - y_0)$$

in which y represents the actual free-board, y_0 the same in cm. when the vessel is fully laden and $\triangle$ the difference between the full tonnage and the real weight of the cargo in tons.

For a vessel with less than half its full cargo on the contrary

$$L = \frac{Eu + Em}{200} (h - h_0)$$

is applicable, where h represents the real depth of immersion, h_0 that of the vessel in cm. when empty and L the weight of the cargo in tons.

According to the above formulae the weight of the cargo for any depth may be calculated and the distances between the dividing lines of the degrees of the guage can be made to correspond in round numbers by intercalation with the degrees of weight.

In the same way by the use of the above formulae the correctness of the guage may be tested.

5) The measurement table mentioned in the Report of July the 18th 1888 may be retained and only requires completion by the addition of formulae for the weight of the cargo after the manner of the following examples.

6) Example. Given or found by measurement:

Depth of empty vessel $ho = 30$ cm.

Depth of fully laden vessel with 40 cm. free-board = 170 cm.

Therefore, difference between higher and lower levels = 170 — 30 = 140 cm.

Area of the floating levels:

$$Eo = 220 \text{ sq. m.}$$
$$Em = 200 \text{ ,, ,,}$$
$$Eu = 160 \text{ ,, ,,}$$

Therefore the tonnage Q is:

$$Q = \frac{140}{6} \times \frac{220 + 4 \,.\, 200 + 160}{100} = 275 \text{ tons.}$$

and the weight of the cargo L with the free board y, so long as y is $<$ 110 cm.

$$L = 275 - \frac{220 + 200}{200} (y - 40) = 275 - 2.1 \ (y \ 40)$$

and when the depth of immersion h is $<$ 100 cm.

$$L = \frac{200 + 160}{200} (h - 30) = 1.80 \ (h - 30).$$

Hence the following results:

Depth of immersion in cm.	170	160	150	140	130	120	110	100
Weight of cargo in tons	275	254	233	212	191	170	149	128
Height of free-board in cm.	40	50	60	70	80	90	100	110

and according to the second formula:

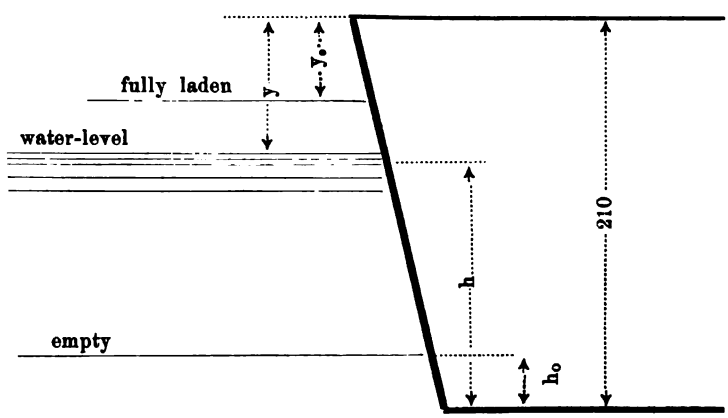
Depth of immersion in cm.	30	40	50	60	70	80	90	100
Weight of cargo in tons	0	18	36	54	72	90	108	126
Height of free-board in cm.	180	170	160	150	140	130	120	110

Thus a cargo of 100 t. corresponds to a depth of immersion of 85.6 cm. and a height of free-board of 124.4 cm.

A cargo of 200 t. correspouds to a depth of immersion of 134. 3 cm. and so forth.

The tonnage of the vessel with 40 cm. height of free-board is 275 tons.

So long as the height of the free-board remains under 110 cm. the weight of the cargo diminishes by 2.10 tons for each cm. less of immersion and further by 1.80 ton for each cm. The following diagram may be of service



7. As no very great exactitude is necessary in the calculation of the weight of the cargo and a difference of a few tons would not be of importance, and as on some inland navigating vessels the area of the floating levels *Eo*, *Em* and *En* do not differ so much as on sea-going vessels, the calculation of the weight of the cargo may be simplified and can be found as nearly as is necessary without taking fresh measurements of the vessel.

For example let the tonnage according to the table of measurements be as above $Q = 275$ tons and the depth of a fully laden vessel with a free-board of 40 cm. 170, and of the same when empty 30 cm.,

cm., or what is the same thing the free-board for loaded or empty be respectively 40 cm. and 180 cm., we can apply this formula:

$$L = \frac{275}{170 - 30} (h - 30)$$

or

$$L = \frac{275}{180 - 40} (y - 48)$$

in which L represents the weight of the cargo with the depth of immersion h and the free-board y.

This formula which however does not differ much from the preceding one gives the following values:

Depth of immersion h in cm.	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30
Weight of cargo L in tons.	275	255	236	216	196	177	157	137	118	98	79	59	39	20	0
Height of free-board in cm.	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180

these simplified means of verification can be applied while the vessel is passing through the lock.

17

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS
THE HAGUE 1894.

5th QUESTION.

TOLLS AND TAXES ON NAVIGABLE WAYS in BELGIUM.

REPORT

BY

M. A. DUFOURNY
Ingénieur principal des Ponts et Chaussées à Bruxelles.

THE HAGUE,
Printed by Belinfante B^{ths}, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

TAXES AND TOLLS

ON

NAVIGABLE WAYS IN BELGIUM.

REPORT

BY

M. A. DUFOURNY,

Ingénieur principal des ponts et chaussées.

SUMMARY.

I. PREFACE.

I propose to reply briefly and in the order in which they have been put to the questions contained in the third section of the work of the Congress, which refers to tolls on navigable ways.

The remarkable reports, which were presented at the Paris Congress in 1892, have rendered much easier the work which remains to be done. They have cleared the ground of discussion and resolved, or thoroughly examined, questions of principle. We have now only to establish the facts of the present situation in the different countries, the rate of tolls, the mode of their collection, control, and the successive phases which have led up to the present state of things.

Viewed from this restricted, but practical point of view, the study is still full

of interest. This we are going to try and prove, but without leaving the bounds which have been assigned to our work and which embrace solely the navigable ways of Belgium.

II. RATES OF TOLLS.

Ways administered by the State.

One of the Orators most listened to in the Belgian Parliament (1) said in 1859 in a well studied speech and supported by documents, that the uniformity of tolls on the canals and rivers of the Country appeared to him a most far off contingency and that he did not hesitate to say that it was absolutely unrealizeable.

„It has been laid before you", he said, „as a thing wich would be eminently desirable. Well, I reply to those who have expressed themselves in this sense, that they have imagined a Utopia; that the uniformity of tolls on Canals and rivers is utterly impossible, and that their dream will never be realized."

What appeared impossible in 1859 has been accomplished, not in one day but gradually, and each step of progress has been influenced by the force of circumstances. A royal decree of June 1st 1886 orders uniformity of tolls on all canals and uniformity of tolls on all rivers administered by the State.

We will say later on what were the circumstances and the necessities the pressure of which brought about this result.

We will somewhat develope this part of our work as we wish to show the various trains of ideas, the different opinions which have been manifested and the successive points of view from which the rights of navigation in Belgium have been regarded in this country of industry and exportation, where the question of transport and tolls has always been regarded, and rightly so, as an essentially vital one.

At the present day, as we have just said, the rate of tolls is uniform on the whole of the system administered by the State. There is one sole rate for canals, one sole rate for canalised rivers. The exceptions to the rule are confined to two or three particular cases.

After a long period of trials and experiments it is recognised that the tariff of dues should be very low and as simple as possible in its application.

The principle of the tariff is elementary. It consists in charging the boats in proportion to their cargo, in tons of 1000 kilogrammes and on the length of their journey in kilomètres.

The kilometric ton is therefore the sole basis of the duty.

---

(1) Chambre des Représentants, p. 56, Séance du 18 Novembre 1859.

The boats are charged at the rate of five millimes per kilometric ton on canals and one millime and six tenths on canalised rivers.

Altogether the kilometric tonnage transported on the system of the State — strictly limited to canals and rivers, on which tolls were levied, and therefore not taking into account maritime traffic — amounted in 1892 to 409,098,611 kilometric tons, which brought into the Treasury in round figures 1,200,000 francs. The kilometric ton paid thus a rate of about 3 millimes. We shall see farther on that this figure is justified and that the rate levied represents very approximately the price of the service rendered to navigation.

Unloaded boats are free from tolls and pay in all only 20 centimes for permission to travel. No tax is levied on rivers which are under the influence of the tide, nor on maritime canals in so far as regards maritime navigation in its proper sense.

Rafts and floats of wood are subject to the same charges as laden boats. A cubic metre of wood is calculated as a ton.

The masters are allowed to decide for themselves whether they pay the dues for the entire journey on one single waterway at the office of departure, or from office to office as the journey proceeds.

In addition to the system of ways administered by the State, which consists of about 1800 kilometres, there are conceded ways with a total length of 95 kilometres, and a system of secondary ways of a local character, which are administered by the provinces, the communes and private syndicates, generally the so called „Wateringues". This system is constituted as follows:

Provinces	119	Kilometres.
Communes	92	„
Wateringues	101	„

Ways administered by the provinces and the Communes.

It is seen that the system of canals administered by the Provinces is of limited extent. It only now exists in Flanders and is of small importance. Most of these canals date back to a remote period. They have long since repaid the cost of their establishment, and in East Flandres they have long since been freed from all dues. In West Flanders the ancient dues have been maintained up to a later date and it was only on the 15th of June 1887 that the decree was issued which freed all provincial canals from tolls.

The communal ways are for the most part, and notably so in Flanders, of very small importance and their traffic is very limited.

On the Callebeek, on the Ghistelles Canal, on the Handzaeme and Zarren Canals and on the Oudenbourg Canal, no dues are levied.

On the other communal canals tolls are charged for the passage of bridges and locks, which are based on complicated, difficult and divergent tarrifs, the irrational origins of which can only be justified by their antiquity.

This is the case on the Eecloo Canal and on the Eecloosch Leiken administered by the town of Eecloo, and on the Lieve, the Meerhem, the

wooden quay canal, and the canal connecting the Lys with the canal from Ghent to Terneuzen, administered by the town of Ghent.

On the Eecloo canals the bridge dues are fixed by the Royal decree of February 21st and of December 12th 1862 as follows:

for all craft of 25 tons or under	10	centimes
" " " " 26 to 75 tons	20	"
" " " " 76 " 150 "	40	"
" " " " 151 " or over	60	"
Rafts and wood floats per mètre	5	"

At Ghent also tolls are collected at the passing of communal turning bridges with the exception of those on the canal connecting the Lys with the canal from Ghent to Terneuzen.

These dues are fixed by the Royal decree of March 31st 1849 of which the tariff is still more complicated than that of Eecloo.

A Quay due of two centimes per ton, fixed and approved by the decree of the Regent of March 1st 1831, is levied on all watercourses traversing the territory of the town, with the exception of those which communicate freely with the Canal from Ghent to Terneuzen and which are considered as belonging to the port of Ghent.

For these waters the dues approved by the Royal decree of December 1st 1880 are fixed at eight centimes per ton for each boat loaded or unloaded at the side of the quays or banks, and at four centimes for every boat in the basin employed in the work of trans-shipment.

The canal from Brussels to the Rupel and the canal from Louvain to the Dyle have been dug at the expense of the towns of Brussels and Louvain respectively. They are both of great importance.

The first of these, generally called the Willebroeck canal, is the oldest in the country and one of the oldest in Europe. It was dug by the town of Brussels in consequence of grants allowed by Marie de Bourgogne on June 4th 1477, and of Charles Quint on November 7th 1531.

The Louvain canal dates back to the time of Marie Thérèse. Its establishment was authorised by a grant of January 21st 1750.

Willebroeck Canal.

Every boat or ship navigating on the Willebroeck Canal is subjécted by the Royal decree of December 30th 1871, Chapter IV, to a navigation due calculated on its tonnage and the importance and nature of its cargo.

The ton is a cubic metre or 1000 kilogrammes for all vessels without distinction.

Boats and ships are with respect to theirs cargo divided into three classes.

Tho 1st class comprises boats laden with materials, merchandise or other objects than those mentioned below.

The 2nd class comprises boats laden with coal of all kinds, bricks, briquettes, tiles, fire-wood, marl, cinders, paving stones, hay, straw, broken glass, bones, sea-water, dung and manure, earth, sand, dike stones, soda, rough and fine salt, rails and sleepers, rough castings, old castings and old iron, skins, rags and old ropes.

The 3rd class comprises empty boats.

The navigation dues are fixed per ton and per reach, viz.:

1st class	6	centimes
2nd "	4½	"
3nd "	2	"

10 centimes is charged for each receipt under 10 francs and 35 centimes, including the cost of receipt stamp, on each receipt for a higher sum than 10 franc.

For boats laden with merchandise belonging to more than one class the dues are charged on the cargo of each class. Boats of less than 10 tons pay for a cargo of this capacity.

Canal from Louvain to the Dyle.

The navigation dues are fixed by the Royal decree of October 17th 1868 at 8 centimes per ton per reach, or 40 centimes for the whole length of the canal including a return journey for ships and boats arriving and departing with cargo.

A reduction of one third is allowed on empty boats and on boats doing a regular service (*bateaux messagers*). A reduction of one half is allowed on boats arriving and departing empty.

The particulars given above show the diversity of the principles on which the dues on the Communal Canals have been fixed. The dissimilarity would have appeared much more complete, if, after the tariffs establishing the tolls, had been inserted the long list of exceptions, rebatement of charges, exemptions and reductions.

Many of the Communal Canals are completely free. Others only partially so, the liberty applying to empty boats, manure-laden boats, boats of which the tonnage is below a certain limit, boats employed in dredging transports for public works, for the administration of the State, to sailing boats, and even regulated by of the number of masts carried. (1)

The unit basis of the application of tariffs is essentially variable according to the navigable way and the conditions of navigation.

At Eecloo and at Ghent it is not the ton of cargo, but the ton of capacity which is taxed. The dues are invariable on certain limits of the way traversed, as the collection only takes place at the passing of certain constructive works. This collection is again complicated by the fact that it is not proportional to the tonnage of the boat, but varies according to a tarrif *à paliers* (landing stages) to employ a term used on railways and applicable in this case.

Another complication, but a much larger one, exists on the canal from Brussels to the Rupel. On this way, as is the case also on the canal from Louvain to the Dyle, the unit is the ton of capacity and not the ton weight, and the unit of distance is the reach, the length of which varies considerably. But this is not all the difficulty in the application, the greatest resulting from the fact that the tariff is differential according to the nature and class of the merchandise.

It is easy to imagine to what confusion such a system must lead when it is a question of mixed cargoes belonging to several different classes. What is then for each of these the quota in tons to be taxed? What should be the volume which any part of the cargo should attain before it is subject to the tariff of its class? What reduction should be made for empty boats? How arrange the tolls when partial dischargements are made in the course of the route?

The arrangement of the tariff on navigable ways administered by concessionary companies reminds us in many respects of the one in force on

---

(1) Art. 2 of Royal decree of May the 31st 1849 (town of Ghent).

and according to the second formula:

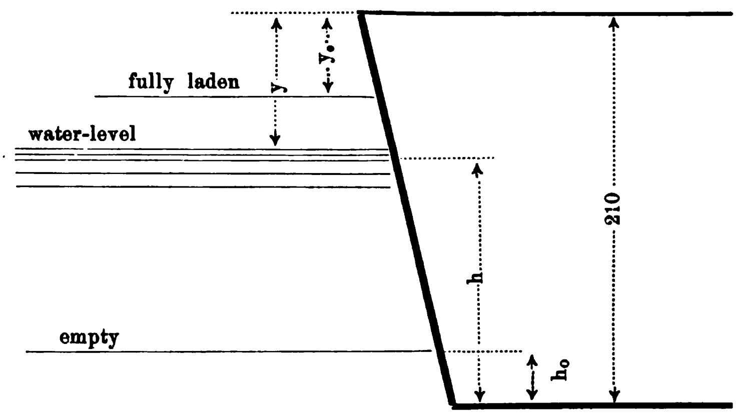
Depth of immersion in cm.	30	40	50	60	70	80	90	100
Weight of cargo in tons	0	18	36	54	72	90	108	126
Height of free-board in cm.	180	170	160	150	140	130	120	110

Thus a cargo of 100 t. corresponds to a depth of immersion of 85.6 cm. and a height of free-board of 124.4 cm.

A cargo of 200 t. corresponds to a depth of immersion of 134. 3 cm. and so forth.

The tonnage of the vessel with 40 cm. height of free-board is 275 tons.

So long as the height of the free-board remains under 110 cm. the weight of the cargo diminishes by 2.10 tons for each cm. less of immersion and further by 1.80 ton for each cm. The following diagram may be of service



7. As no very great exactitude is necessary in the calculation of the weight of the cargo and a difference of a few tons would not be of importance, and as on some inland navigating vessels the area of the floating levels *Eo*, *Em* and *En* do not differ so much as on sea-going vessels, the calculation of the weight of the cargo may be simplified and can be found as nearly as is necessary without taking fresh measurements of the vessel.

For example let the tonnage according to the table of measurements be as above $Q = 275$ tons and the depth of a fully laden vessel with a free-board of 40 cm. 170, and of the same when empty 30 cm.,

cm., or what is the same thing the free-board for loaded or empty be respectively 40 cm. and 180 cm., we can apply this formula:

$$L = \frac{275}{170 - 30} (h - 30)$$

or

$$L = \frac{275}{180 - 40} (y - 48)$$

in which L represents the weight of the cargo with the depth of immersion h and the free-board y.

This formula which however does not differ much from the preceding one gives the following values:

Depth of immersion *h* **in cm.**	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30
Weight of cargo *L* **in tons.**	275	255	236	216	196	177	157	137	118	98	79	59	39	20	0
Height of free-board in cm.	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180

these simplified means of verification can be applied while the vessel is passing through the lock.

17

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS
THE HAGUE 1894.

5th QUESTION.

TOLLS AND TAXES ON NAVIGABLE WAYS in BELGIUM.

REPORT

BY

M. A. DUFOURNY
Ingénieur principal des Ponts et Chaussées à Bruxelles.

THE HAGUE,
Printed by Belinfante B^{ths}, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

TAXES AND TOLLS

ON

NAVIGABLE WAYS IN BELGIUM.

REPORT

BY

M. A. DUFOURNY,

Ingénieur principal des ponts et chaussées.

SUMMARY.

I. PREFACE.

I propose to reply briefly and in the order in which they have been put to the questions contained in the third section of the work of the Congress, which refers to tolls on navigable ways.

The remarkable reports, which were presented at the Paris Congress in 1892, have rendered much easier the work which remains to be done. They have cleared the ground of discussion and resolved, or thoroughly examined, questions of principle. We have now only to establish the facts of the present situation in the different countries, the rate of tolls, the mode of their collection, control, and the successive phases which have led up to the present state of things.

Viewed from this restricted, but practical point of view, the study is still full

of interest. This we are going to try and prove, but without leaving the bounds which have been assigned to our work and which embrace solely the navigable ways of Belgium.

II. RATES OF TOLLS.

Ways administered by the State.

One of the Orators most listened to in the Belgian Parliament (1) said in 1859 in a well studied speech and supported by documents, that the uniformity of tolls on the canals and rivers of the Country appeared to him a most far off contingency and that he did not hesitate to say that it was absolutely unrealizeable.

„It has been laid before you", he said, „as a thing wich would be eminently desirable. Well, I reply to those who have expressed themselves in this sense, that they have imagined a Utopia; that the uniformity of tolls on Canals and rivers is utterly impossible, and that their dream will never be realized."

What appeared impossible in 1859 has been accomplished, not in one day but gradually, and each step of progress has been influenced by the force of circumstances. A royal decree of June 1st 1886 orders uniformity of tolls on all canals and uniformity of tolls on all rivers administered by the State.

We will say later on what were the circumstances and the necessities the pressure of which brought about this result.

We will somewhat develope this part of our work as we wish to show the various trains of ideas, the different opinions which have been manifested and the successive points of view from which the rights of navigation in Belgium have been regarded in this country of industry and exportation, where the question of transport and tolls has always been regarded, and rightly so, as an essentially vital one.

At the present day, as we have just said, the rate of tolls is uniform on the whole of the system administered by the State. There is one sole rate for canals, one sole rate for canalised rivers. The exceptions to the rule are confined to two or three particular cases.

After a long period of trials and experiments it is recognised that the tariff of dues should be very low and as simple as possible in its application.

The principle of the tariff is elementary. It consists in charging the boats in proportion to their cargo, in tons of 1000 kilogrammes and on the length of their journey in kilomètres.

The kilometric ton is therefore the sole basis of the duty.

---

(1) Chambre des Représentants, p. 56, Séance du 18 Novembre 1859.

The boats are charged at the rate of five millimes per kilometric ton on canals and one millime and six tenths on canalised rivers.

Altogether the kilometric tonnage transported on the system of the State — strictly limited to canals and rivers, on which tolls were levied, and therefore not taking into account maritime traffic — amounted in 1892 to 409,098,611 kilometric tons, which brought into the Treasury in round figures 1,200,000 francs. The kilometric ton paid thus a rate of about 3 millimes. We shall see farther on that this figure is justified and that the rate levied represents very approximately the price of the service rendered to navigation.

Unloaded boats are free from tolls and pay in all only 20 centimes for permission to travel. No tax is levied on rivers which are under the influence of the tide, nor on maritime canals in so far as regards maritime navigation in its proper sense.

Rafts and floats of wood are subject to the same charges as laden boats. A cubic metre of wood is calculated as a ton.

The masters are allowed to decide for themselves whether they pay the dues for the entire journey on one single waterway at the office of departure, or from office to office as the journey proceeds.

In addition to the system of ways administered by the State, which consists of about 1800 kilometres, there are conceded ways with a total length of 95 kilometres, and a system of secondary ways of a local character, which are administered by the provinces, the communes and private syndicates, generally the so called „Wateringues". This system is constituted as follows:

Provinces	119 Kilometres.
Communes	92 „
Wateringues	101 „

Ways administered by the provinces and the Communes.

It is seen that the system of canals administered by the Provinces is of limited extent. It only now exists in Flanders and is of small importance. Most of these canals date back to a remote period. They have long since repaid the cost of their establishment, and in East Flandres they have long since been freed from all dues. In West Flanders the ancient dues have been maintained up to a later date and it was only on the 15th of June 1887 that the decree was issued which freed all provincial canals from tolls.

The communal ways are for the most part, and notably so in Flanders, of very small importance and their traffic is very limited.

On the Callebeek, on the Ghistelles Canal, on the Handzaeme and Zarren Canals and on the Oudenbourg Canal, no dues are levied.

On the other communal canals tolls are charged for the passage of bridges aud locks, which are based on complicated, difficult and divergent tarrifs, the irrational origins of which can only be justified by their antiquity.

This is the case on the Eecloo Canal and on the Eecloosch Leiken administered by the town of Eecloo, and on the Lieve, the Meerhem, the

wooden quay canal, and the canal connecting the Lys with the canal from Ghent to Terneuzen, administered by the town of Ghent.

On the Eecloo canals the bridge dues are fixed by the Royal decree of February 21st and of December 12th 1862 as follows:

for all craft of 25 tons or under	10 centimes
" " " " 26 to 75 tons	20 "
" " " " 76 " 150 "	40 "
" " " " 151 " or over	60 "
Rafts and wood floats per mètre	5 "

At Ghent also tolls are collected at the passing of communal turning bridges with the exception of those on the canal connecting the Lys with the canal from Ghent to Terneuzen.

These dues are fixed by the Royal decree of March 31st 1849 of which the tariff is still more complicated than that of Eecloo.

A Quay due of two centimes per ton, fixed and approved by the decree of the Regent of March 1st 1831, is levied on all watercourses traversing the territory of the town, with the exception of those which communicate freely with the Canal from Ghent to Terneuzen and which are considered as belonging to the port of Ghent.

For these waters the dues approved by the Royal decree of December 1st 1880 are fixed at eight centimes per ton for each boat loaded or unloaded at the side of the quays or banks, and at four centimes for every boat in the basin employed in the work of trans-shipment.

The canal from Brussels to the Rupel and the canal from Louvain to the Dyle have been dug at the expense of the towns of Brussels and Louvain respectively. They are both of great importance.

The first of these, generally called the Willebroeck canal, is the oldest in the country and one of the oldest in Europe. It was dug by the town of Brussels in consequence of grants allowed by Marie de Bourgogne on June 4th 1477, and of Charles Quint on November 7th 1531.

The Louvain canal dates back to the time of Marie Thérèse. Its establishment was authorised by a grant of January 21st 1750.

Willebroeck Canal.

Every boat or ship navigating on the Willebroeck Canal is subjected by the Royal decree of December 30th 1871, Chapter IV, to a navigation due calculated on its tonnage and the importance and nature of its cargo.

The ton is a cubic metre or 1000 kilogrammes for all vessels without distinction.

Boats and ships are with respect to theirs cargo divided into three classes.

The 1st class comprises boats laden with materials, merchandise or other objects than those mentioned below.

The 2nd class comprises boats laden with coal of all kinds, bricks, briquettes, tiles, firewood, marl, cinders, paving stones, hay, straw, broken glass, bones, sea-water, dung and manure, earth, sand, dike stones, soda, rough and fine salt, rails and sleepers, rough castings, old castings and old iron, skins, rags and old ropes.

The 3rd class comprises empty boats.

The navigation dues are fixed per ton and per reach, viz.:

1st class	6 centimes
2nd "	4½ "
3rd "	2 "

10 centimes is charged for each receipt under 10 francs and 35 centimes, including the cost of receipt stamp, on each receipt for a higher sum than 10 franc.

For boats laden with merchandise belonging to more than one class the dues are charged on the cargo of each class. Boats of less than 10 tons pay for a cargo of this capacity.

Canal from Louvain to the Dyle.

The navigation dues are fixed by the Royal decree of October 17th 1868 at 8 centimes per ton per reach, or 40 centimes for the whole length of the canal including a return journey for ships and boats arriving and departing with cargo.

A reduction of one third is allowed on empty boats and on boats doing a regular service (*bateaux messagers*). A reduction of one half is allowed on boats arriving and departing empty.

The particulars given above show the diversity of the principles on which the dues on the Communal Canals have been fixed. The dissimilarity would have appeared much more complete, if, after the tariffs establishing the tolls, had been inserted the long list of exceptions, rebatement of charges, exemptions and reductions.

Many of the Communal Canals are completely free. Others only partially so, the liberty applying to empty boats, manure-laden boats, boats of which the tonnage is below a certain limit, boats employed in dredging transports for public works, for the administration of the State, to sailing boats, and even regulated by of the number of masts carried. (1)

The unit basis of the application of tariffs is essentially variable according to the navigable way and the conditions of navigation.

At Eecloo and at Ghent it is not the ton of cargo, but the ton of capacity which is taxed. The dues are invariable on certain limits of the way traversed, as the collection only takes place at the passing of certain constructive works. This collection is again complicated by the fact that it is not proportional to the tonnage of the boat, but varies according to a tarrif *à paliers* (landing stages) to employ a term used on railways and applicable in this case.

Another complication, but a much larger one, exists on the canal from Brussels to the Rupel. On this way, as is the case also on the canal from Louvain to the Dyle, the unit is the ton of capacity and not the ton weight, and the unit of distance is the reach, the length of which varies considerably. But this is not all the difficulty in the application, the greatest resulting from the fact that the tariff is differential according to the nature and class of the merchandise.

It is easy to imagine to what confusion such a system must lead when it is a question of mixed cargoes belonging to several different classes. What is then for each of these the quota in tons to be taxed? What should be the volume which any part of the cargo should attain before it is subject to the tariff of its class? What reduction should be made for empty boats? How arrange the tolls when partial dischargements are made in the course of the route?

The arrangement of the tariff on navigable ways administered by concessionary companies reminds us in many respects of the one in force on

---

(1) Art. 2 of Royal decree of May the 31st 1849 (town of Ghent).

the Willebroeck Canal. We will refer to this point, which requires some development, at the end of this chapter.

We have dwelt rather long on the subject of the principles and rules applied for the collecton of navigation dues on communal Canals; we have pointed out their discordance and their complications with the object of bringing more into relief the simplicity and the facility of application of the taxes applied by the government in 1886 on the whole of the State system. These uniform taxes reduced to an average of three millimes per ton per kilomètre have only been brought to this rate and to this uniformity after many years of discussion, repeated trials and innumerable experiments.

Tariffs successively applied on the system of navigable ways of the Belgian State.

There was a time, and it is not very remote, when the tariffs of the system of the State were still more confused, more complicated and more incoherent than those in use on the Communal ways.

If we look back only thirty years, and study the tariffs of the State at this period, we find between the rates of neighbouring lines and even between sections of one and the same line such dissimilarity, want of consequence and connection, such striking diversity and confusion, that order has really disappeared.

We think it might be useful to show to what an extent these tariffs were entangled, and to take a rapid retrospective view of the different phases which the Belgian tarification has passed through. We will point out how by successive steps of progress, how in eliminating, simplifying and resolutely pruning in the bewildering heap of exceptions and particular cases, which seemed created merely for amusement, the rules at present in use have been arrived at.

In order to render the reading of this report less difficult we have drawn out and grouped in the form of a table (1) the important dates and the most usefull elements in the history of tolls on the principal navigable ways of Belgium.

We can thus be more concise and need only dwell in the course of our report on prominent points which it is necessary to bear in mind, in order to have a fair view of the chain of facts and to comprehend the motives which have brought about the successive transformations and reductions in the tariffs. We shall thus follow step by step the way that has been traversed and we shall see how, by degrees, light has been imperceptibly shed on the question.

It was at the beginning of the present century that the Belgian system of canals underwent its greatest extension. With the development of the coal trade it was necessary to find an easy and economical means of bringing the coals of Mons and Charleroi to the markets of Paris and

(1) Annex No. 1.

the North of France, as well as to the markets of Brussels, Ghent and Antwerp.

With this object, and almost simultaneonsly, the excavation of the canal from Mons to Condé and the work of canalising the Sambre were taken in hand. These waterways were to serve the French markets. The following direct communications were also effected: by the canal from Pommerseul to Antoing the basin of Mons was connected with the markets of Flanders and the province of Antwerp; and by the canal from Charleroi to Brussels the basins of Charleroi and the Centre were joined with the principal markets of Brabant and the north of the country.

A little later the works of the „Canal de l'Espierres" were commenced, which placed the chalk basin of Tournai in communication with Roubaix, Tourcoing and Lille, the most populous and busiest centres of the North of France. The Campine canals were only commenced in 1850, their purpose being to serve at the same time agricultural and industrial interests.

Originially the tolls levied on the coal canals were very high; reduced to the ton-kilomètre tariff they were as follows: $5^{6}/_{10}$ centimes on the canal from Pommeroeul to Antoing, $4^{7}/_{10}$ centimes on the canal from Charleroi to Brussels, 5 centimes on the Sambre, and 11 centimes on the „canal de l'Espierres".

A general principle governed this tarification. An endeavour was made to discover a rate of tolls which would according to a presumed, hypothetical tonnage serve to redeem the capital employed, pay interest and cover the expenses of maintainance and working.

A certain balance, to adhere to the expression of the period, existed between the rates in use on the coal canals, because they had been regulated by one and the same administration.

Soon, however, this balance was broken, and this was not by virtue of a system of commercial calculation, nor was it caused by the influence of competition, but it was the consequence of considerations completely foreign to any idea of this nature.

The decree of December 17th 1819 had relieved the State of the administration of navigable ways and placed it in charge of the Provinces.

From this moment, which it is important to note and which constitutes a conspicuous date in the history of tolls in Belgium, every canal and every river was in some way subjected to a particular tariff. There was no longer any general idea, no collective view in the tarification. It was entirely delivered over to chance and the unforeseen, to provincial and local interests. At the end of merely a few years the most complete confusion reigned in matters of tariffs, it was a veritable chaos, an inextricable labyrinth. — The tariff annexed to this report speaks volumes on this subject.

It was impossible for shippers of goods, as well as for boatmen,

to understand the figures and arrangements of tolls and to make a calculation of rates, even approximately, for journeys comparatively limited.

Not to speak of exceptions and reductions, which very much complicated the problem, all calculation was hindered by the diversity of the bases and units employed.

On one and the same waterway, for example, on the Scheldt all was changed when a boat passed from one province to another, the units of measure, the monetary units, the units of distance and the number of units.

Very often money was counted differently on the different services working these rivers. The ton of the Meuse was calculated in cubic ells, and the ton of the Scheldt in cubic metres, the gauge serving as basis for the license (*patente*) and the gauge according to which navigation dues were collected were constituted in different tons; the Belgian ton on maritime ways and the cubic ton were likewise different.

With regard to distances, the toll was generaly fixed by league of five kilometres traversed; but there was a payment also by reach with supplementary dues in certain provinces at the passing of particular constructive works.

On the canal from Charleroi to Brussels the dues were the same for vessels coming from the Sambre and traversing all the Canal as for those coming from the branches of the Centre, although the distances were in the relative proportion of 15 to 3.

There were anomalies still more inexplicable; thus, for instance, if a boat went out of its way, and consequently made a longer journey, in order to avoid a Canal oppressed with exhorbitant taxes, the Canal from Pommeroenl to Antoing, or the Canal de l'Espierres for example, it was obliged to pay a special tax for the profit of the way which it had not followed, and therefore, for the traverse of a distance which it had not covered. Long distances were surtaxed for the benefit of shorter ones and the traffic, an evident injustice, paid for a service which had not been rendered.

Finally, to give an idea of the incoherence which ruled in the collection of tariffs, it must be added, that on many waterways the tolls were differential according to the nature of the merchandise and the tonnage of the boats. A difference was made again accordingly as the boat was laden, half-laden or empty and as it was ascending or descending.

It was the more difficult at this period to think of establishing uniformity of dues as the different provinces endeavoured in the first place to take local interests into account and had to consider the object with which the canal was constructed and customs which had existed perhaps from times immemorial.

The canals of Flanders, for example, having been constructed at a remote period by the communes at their own expense to serve at the

same time for land-drainage and for navigation, it would have seemed contrary to equity to abolish the dues, although they were small, and a most lively opposition would have been raised if with the sole object of uniformity any attempt had been made to touch dues consecrated by the use of centuries.

The country was soon burdened by the numerous inconveniences presented by the system of rivers and canals abandoned to the rule of the provinces and thus deprived of the strength and power which concentration and unity of rule and management afford.

From 1840 the Government was constrained, so to speak, to take back under its own charge sucessively one after the other all the waterways which had been handed over to the provincial administrations. And now commenced the era of relief and reduction.

In 1840—1847—1849—1852 the dues on the Sambre were lowered step by step.

It was the same in 1842—1846—1852 on the canal from Maestricht to Bois-le-Duc; in 1849 on the canal from Charleroi to Brussels; in 1851 on the canal from Pommeroeul to Antoing and on the canal from Mons to Condé.

One circumstance, an unparalleled stimulant, forcibly led up to these reductions, the competition of railways, which, born yesterday, already covered the country and affected transports with profit at a rate so cheap, as to be surprising for that period and due to a collective organisation strongly and wisely combined and at tariffs logically and rationally based on the service rendered.

The navigable ways had from this time forward a redoutable competitor, a model which it was necessary to follow, or to suffer decay.

The enormous influence which the example of the railways exercised on the tarification of navigable ways in Belgium cannot be denied.

It required this example as an incentive to well-doing, to advancement in the way of progress, for the release of our tariffs from the faults and complications in which inertia and routine had held them bound.

In the beginning at the retaking of the canals and rivers by the State, this body confined itself to reducing the tolls, but there was no question of unifying or simplifying them.

Ideas on this subject were most confused. The Government believed that it was its duty to maintain the equilibrium, the balance between the different industries of the country. It was admitted in principle that the State could at will divide and limit wealth and notably the transports of the different coal basins; and so strong was the conviction of the equity and justice of this rôle that one of the most powerful men in the country (1) declared in 1847 from the parliamentary tribune that „it was

(1) See parliamentary Annals. December the 22 1847 p. 1269.

an essential condition and first necessity to have inserted in the act of concession of the Charleroi Canal that the basins of Charleroi and of Brussels should not enjoy the position which their typographical situation was about to afford them, and that the coals of the Centre, although traversing only the half of the canal should pay the total of the dues, the same as paid by the coals of Charleroi, which traversed the entire length."

Why so, said he?

„In order not to annihilate the coals of Charleroi, which would no longer be able to sustain competition with those of the Centre in markets of which they were already in possession. It is in the same act which created the canal that is found this *equitable and truly paternal sentiment so preservative of acquired positions.*"

Such were the ideas which prevailed in 1847. But they made rapid progress; the railways were there, competition kept the game alive, true economical principles came to light and the Belgian Government began to be imbued with this doctrine, which has since been so well consecrated by facts, that commercial liberty is the most fruitful source of wealth, and that the removal of obstacles gives to means of transport, and consequently to the production of industry, their greatest sum of usefulness.

Canals are not made, it was said in 1859, (1) to create revenues for those who make them; but to multiply relations, productions, exchange, to develope commerce and render industry more active.

When the expenses of establishment, the interest on the capital furnished and the expenses of maintainance have been regained on a public service, is it right to require complementary receipts?

As soon as these are no longer merely remuneration for a service long since paid for, they become a tax. They become a tax on commerce and industry, a tax on the real tools of production, a tax from that moment arbitrary, unjust and anti-economical. Under the influence of such ideas progress was necessarily incessant. The deputies of industrial centres too allowed to the Government no rest on the subject, but required at any price reform of the toll-tariffs on canals and rivers.

The question was repeatedly the object of important discussion in the Chambre and from 1853 to 1858 the discussions were renewed each year at the discussion of the budget of Ways and Means.

Repeated petitions furnished with numerous signatures were constantly presented to bear witness to the extreme eagerness of the interested parties to obtain a solution.

In 1856 the draught of a Bill was submitted and for the first time a central section expressed a wish to see navigation dues simultaneonsly unified and lowered on the entire system of the country.

(1) See parliamentary Annals. Chambre des Représentants, p. 13, 10 Novembre 1859.

With this object the Government instituted two years later a commission whose study and work were most remarkable and which caused a great step to be taken in the question of tariffs.

The commission of 1858 thoroughly studied the subject; it produced a completely collective work on navigable ways, at the present day still most valuable, embracing at once an examination of the hydraulic system from technical, historical and financial points of view. (1)

Such a work could not fail to bring into full light the want of similarity of dimensions and form adopted for the canals, the incoherence of their tariffs and the shocking manner in which they were established from the point of view of distributive justice, of equality before the law, and of the interest of our industries.

It was then seen, and it was a revelation, that certain canals had reimbursed several times over and long since their cost of construction and all expenses relating to them. The Charleroi Canal had furnished in certain years more than one million net profit to the State, all expenses and interest deducted. It gave again $8^1/_4$ % interest in 1858; at the same date the canal from Mons to Condé gave 7 %. And these important ways, of which the expense had been so liberally reimbursed to the Treasury, were the most taxed and the most heavily oppressed by tariffs.

The enquiry, while pointing out the faults of the existing situation, brought forth a series of measures for remedying them. It proposed to reduce by 40 % the dues on the Charleroi canal and by 50 % the dues on the Campine canals.

The so-called „equilibrium" tariffs, that is to say the tariffs which were constant, whatever might be the distance traversed, were actively attacked, as were also the differential tariffs and the double gauge for licence and for navigation dues.

A distinguished engineer, a member of the Commission, taking his inspiration from the mode of tarification adopted for railway traffic, maintained with talent and energy, without, however, rallying his colleages to his idea, that the toll-tariff should decrease in proportion to the distance to be traversed and include a fixed due payable at the point of embarcation. In addition he examined the question of the realization of an ideal very difficult to attain for transports on waterways, that is the reduction of freights in proportion to the distance traversed.

With this view he subdivided the hydraulic system in categories of ways, according to the facilities which they respectively offer to navigation and

(1) The lengths and forms of the ways, dimensions of plant and especially of locks, anchorages, dates of construction of retaking or repurchasing and of working, the mode of collecting tolls in 1858, and previous tariffs, expenses of construction, expenses of maintainance and of staff, ordinary receipts and accessory produce and finally statistics of traffic, were objects of carefully compiled reports and of attentive discussion.

he calculated the rate of tolls in inverse ratio to the difficulties of towage or of traction. This theoretical conception remained without result.

The conclusions of the Commission of 1858 were sanctioned by the law of February 19th 1860.

By the terms of this law the Government was authorised:

1°. To substitute for the different modes of collection one uniform system according to which the dues should be collected per league in the following manner:

A. Per ton of cargo	3/5;
B. " " " capacity	1/5;
C. " " " " (returning empty) . . .	1/5;

2°. To apply on every river a due per league of distance traversed equal to the average of the different dues which were at that time in force.

3°. To establish on every navigable way one sole rate, without distinction of class, taking for basis the rate applied to pit-coal.

4°. To reduce by 40 % the rates levied on the canal from Charleroi to Brussels and by 50 % those on the canals from Liége to Antwerp.

The law of 1860 did not solve the question of tolls; it was left open. An important step had been taken in the sense of greater uniformity, and a more just assessment; but it was desired to go further; the reform was incomplete and the progress realized insufficient.

There remained in fact two bases of application for the collection of tolls: the ton of capacity of the boat and the ton burden; hence arose difficulties in calculations and in documents, long delays at the collecting offices, great confusion in the application of the rates, and anomalies such as, that a boat fully loaded was taxed, for example at a rate of 5 centimes per league per ton of cargo, while the tax amounted to 7 centimes when the boat was only half loaded.

On the other hand, as we have already observed, the 2nd article of the law of 1860 had only made uniform by averages the dues relating to one and the same way. At this time there remained 37 different tariffs in use on the systems of the Belgian State. The rate of tolls varied on the canals in the proportion of 1 to 15 (1).

The tolls on certain canalised rivers were eight or nine times higher than on certain canals.

On comparing the tolls on rivers only we find that they varied in the proportion of 1 to 4.

Immediately after the vote of the law of 1860, its result was questioned, and its revision was voted by an order of the day. With this object a commission was instituted by the decree of June 29th 1864. It showed

(1) See Chambre des Représentants, séance du 14. Avril 1863, n°. 132.

diligence and a few weeks after its institution it submitted for the approbation of the Government, as the result of its labours, a collection of wishes, some of which indicate ideas very advanced for the period and a profound acquaintance with the necessities of interior navigation.

The following were the wishes exrpessed:

1. That the Belgian Government determine by an international convention dimensions for a uniform type of constructive works on canals of interior navigation, that these dimensions be for locks in every case equal to those adopted on the way from Liège to Antwerp, viz., 50 metres in length, 7 metres in width and with a draft of water of 1 m. 20.

2. That the Government establish towing-paths at the sides of the rivers, in the same way as on the sides of the canals in such condition as to admit of the employment of horses for the towage of boats.

3. That *trématage* be allowed to boats drawn by horses.

4. That the Government consider the question of the application of steam to towage.

5. That there be published a general toll tariff for transport by water from the principal points of departure to the principal points of arrival, according to the system in use on railways, in endeavouring, if possible, to realize differential and reducible tariffs in proportion to the distances traversed.

6. That the tolls may be paid in one sum for the entire distance as on railways.

7. That exact and reasonable statistics be established to record the movements of transports effected on waterways.

8. That the Government reduce the tolls on conceded canals to a uniform rate, as on the State Ways.

9. Finally, and this wish is most important with regard to tolls: that the Government modify the mode of collection prescribed by the law of 1860, and substitute one sole tax based solely on the cargo, to replace the fractional rate in proportion to the cargo, to the capacity of the boat and to boats returning empty".

The Government admitted this last wish and requested from the Legislature the necessary powers for simplifying and reducing the tariffs in force.

The law of July 1st 1865 conferred these powers. By its 2nd article it abolished the tripartite division of the basis prescribed by the law of 1860, retaining as basis the real cargo

The kilometre was substituted for the league and a maximum was assigned to the kilometric tax.

The law said, in fact:

The Government is authorised to regulate the tolls on navigable ways administered by the State in such manner that the maximum of these tolls reduced to kilometric tons does not exceed the following units of transport:

One centime for canals;

Three-quarters of a centime for canalised rivers;

Two-tenths of a centime for rivers.

The Government is authorised to take the necessary measures for modifying the present system of collecting navigation dues by the substitution of one tax based solely on the cargo, in place of the fractional rate in proportion to the cargo, to the capacity of the boat and to boats returning empty.

This law of 1865 has been the point of departure of all the progress since accomplished in matters of tolls. Numerous reductions and simplifications of rates have been realized in proportion as reductions were accorded on the railways. It was necessary to follow this terrible adversary on the field of competition, to counterbalance his influence and to endeavour by the low price of transport and the reduction of tolls to retain

for the navigable ways the advantages they possessed for long distances and heavy transports.

Thanks to successive reductions it has been possible to maintain and even to develope the movement of traffic on the navigable ways.

According to the calculations of the Government Commission of which we have spoken, this movement amounted in 1858 to a total 336,062,755 kilometric tons on ways administered by the State and subject to toll. In 1880 on the same ways the traffic was 362,116,000 kilometric tons, in 1888 it reached the figure 367,551,508, and 409,098,611 in 1892. The total movement of transports on the navigable ways of Belgium, including the provincial, communal and conceded ways, and ways exempted from tolls was in 1888, 587,118,251 kilometric tons; in 1892 it amounted to 623,434,111 kilometric tons and in 1893 to 660 millions.

The decree of June 1st 1886, the essential points of which were applied to the Sambre on April 25th 1887, is the last and most important of the acts of the Government in application of the law of 1865 to unify as completely as possible the tariff in use in Belgium on the hydraulic system.

It was in virtue of this decree that the dues levied were reduced by ton and by kilometre to 5 millimes on canals, and to $1^6/_{10}$ millimes on rivers.

The average rate is 3 millimes, and its application to the State system produces annually about 1,200,000 francs (1).

The expenses of maintainance on navigable ways administered by the State, deducting tidal rivers, on which no tolls are levied, is in round figures 1,500,000 francs (2).

If from this sum be deducted the cost of dredging, of consolidation of the slopes necessitated by the efflux of water, for as we have said, most of the Belgian canals are evacuation canals, we find that the receipts cover almost exactly the expenses caused by navigation.

The receipts thus pay the service rendered.

We have shown, also, in our report before the Manchester Congress that the salaries of the administrative staff attached exclusively to the service of navigation find their counterpart in the indirect receipts accruing to the administration, and notably from the letting of land, fishing, plantations, pasturage, ferries and water-crossings etc. (3).

Of the foregoing, a point not to be lost sight of is, that in Belgium the

(1) 1,200,609 in 1889, 1,162,509 in 1890 and 1.195,092 in 1891.

(2) 1,502,477 in 1890 not including expenses relating to tidal rivers.

(3) In 1890 the total of these receipts amounted to 308,929 francs and in 1891 to 248,377; the effective staff attached exclusively to the navigation service cost 415,000 francs.

dues levied on navigation are strictly limited to the taxes neccessary to cover the expenses incurred by the administration for the benefit of the barge traffic.

Conceded ways have not had the benefit of the reductions effected by the State on its own administration. They have, however, by force of circumstances obtained successive partial exemptions, the list of which is not of great interest.

At the present day the rates levied on conceded ways are as follows:

Canal from Blaton to Ath:

The rates are fixed per kilometre in proportion to the distance actually traversed, but with a minimum of 2 kilometres, in the following manner:

per ton of cargo	fr. 0,024
" " capacity of the boat	" 0,008
" " " " (returning empty) . . .	" 0,006

Canalised Dendre.

On this river the dues are levied in the same manner but the rate is lower. It is:

per ton of cargo	fr. 0,006
" " capacity	" 0,002
" " (returning empty)	" 0,002

These tariffs are, however, differential and variable according to the distance traversed, as we shall see later on.

L'Espierres Canal.

The rate varies with the distance traversed, the nature of the merchandise transported and the importance of the cargo. The tariff of the company is fixed as follows:

a. For the entire length of the canal (8.408 km.).

loaded:
- fr. 0.16 per ton of cargo on manure, cinders and lime for agricultural use.
- " 0.24 per ton of cargo on sand, paving stones, broken stones (déchets) and ballast.
- " 0.30 per ton of cargo on all other merchandises.

empty: fr. 0.10 per ton capacity of the boat up to a depth of 1.80 m. with a maximum of 22 francs.

b. For a partial distance per kilometre:

loaded:
- fr. 0.03 per ton of cargo on dung, cinders and manure for agricultural use.
- " 0.04 per ton cargo on sand, paving stones, broken stones (*déchets de pierres*) and ballast.
- " 0.07 per ton of cargo on all other merchandise.

fr 0.02 per ton of capacity of the boat up to a depth of 1.80 m. with a maximum of 22 francs.

Remarks. — Concessionnary companies are allowed to reduce their tariffs in a general manner and without exception on the authority of a decision of the Minister of Public Works.

III. INFLUENCE OF THE DISTANCE TRAVERSED.

The developments which we have given to the first part of this work will save us from entering here into very long details.

We have seen by our historical sketch, how, by successive stages, after having had applied the so-called „equilibrium" tariffs, by which the tolls remained the same on one and the same way whatever might be the distance traversed, and how, after the tariffs by reach, the present tariffs were arrived at, by which the dues are levied on all the State system in proportion to the distances traversed. It is now only the communal canals which deviate from this rule. On the communal canals of Ghent and Eecloo dues are collected for the right of passage without reference to the distance traversed. On the canals of Brussels and of Louvain the tolls are established by reach and are even not then in mathematical proportion to the distance traversed.

On the ways conceded to the Canalised Dendre Company the tariffs have been very cleverly combined; their base is differential, they decrease with the distance traversed and they are studied in manner to attract towards the Dendre transports which would without these tariffs naturally go to the competing ways, the Scheldt and the Lys.

The Dendre Company, whose concession is very limited, extending to scarcely 85 kilometres of way between Blaton and Termonde, has succeeded by a profound study of the conditions of transport on the lines, which border its own, or which rival it, to indirectly extend its concession to a zone of a large radius. With this object in view the company has made itself not only concessionary of tolls, but forwarding agent and contractor of transports. The tariffs are calculated, so as to give the line its maximum of traffic; they are inspired by the example of the railways. They foresee all the cases of a service administered by water, winter, summer, ascent, descent, total or partial traverse, with and without traction, loaded and empty; they form a very complete collection and apply to all the operations and alls the constitutive parts of transport: the boat, its capacity and cargo. These multifarious combinations and these complicated tarifications are not possible except on a small system and to a company of well organised administration. We should like to lay special stress on this point.

The following are the most important parts of the tariffs of the canalised Dendre and of the canal from Blaton to Ath, which it is the subject of the present chapter to make particularly prominent.

Tariff no. 1. — **For intermediate distances** between Blaton and Termonde in both directions:

a. On the canal from Blaton to Ath.

Per ton of cargo fr 0.022 to fr 0.024 per kilm. according to the point of embarcation.
" " " capacity fr 0.008 per kilm. " " "
" " " " returning empty fr 0.008 per kilm. " " "

b. On the canalised Dendre.

Per ton of cargo fr 0.006 per kilometre.
" " " capacity fr 0.002 per kilometre.
" " " " (returning empty) fr 0.002 per kilometre.

Tariff n°. 2. — For the entire distance from Termonde to Blaton and for the entire distance from Blaton to Termonde for boats in destination to all points **below Termonde**.

c. For the ascent (winter season).

Per ton of cargo	fr. 0.894	for the entire distance.
" " " capacity	" 0.306	" " " "
" " " " (returning empty)	" 0.306	" " " "

Ascent (summer season).

Per ton of cargo	fr. 0.853	" " " "
" " " capacity	" 0.306	" " " "
" " " " (returning empty)	" 0.306	" " " "

d. Descent (all seasons).

Per ton of cargo	fr. 0.728	" " " "
" " " capacity	" 0.306	" " " "
" " " " (returning empty)	" 0.306	" " " "

Tariff n°. 3. — For the entire distance between Blaton and Termonde, for boats in destination to localities situated on the Scheldt, above Termonde, **up to Wetteren** (Wetteren not included):

Per ton of cargo	fr. 0.638	for the entire distance.
" " " capacity	" 0.306	" " " "
" " " " (returning empty)	" 0.306	" " " "

Tariff n°. 4. — For the entire distance from Blaton to Termonde, boats loaded for the localities of Wetteren up to Ghent. (Ghent not included);

2°. For the **entire distance** from Blaton to Termonde, of all boats coming from France and from the basin of Tournay.

Per ton of cargo	fr. 0.508	for entire distance.
" " " capacity	" 0.220	" " "
" " " " (returning empty)	" 0.306	" " "

Tariff n°. 5. — For the entire distance from Blaton to Termonde for boats loaded for **Ghent and further**:

Per ton of cargo	fr. 0.458	for the entire distance
" " " capacity	" 0.170	" " " "
" " " " returning empty	" 0.306	" " " "

Tariff n°. 6. — For the entire distance from Termonde to Blaton for loaded boats coming from **Ghent or further**:

2. For the **entire distance** from Termonde to Blaton for boats coming from the Lower Scheldt in **destination to places in France** situated between Douai and Roubaix and further:

Winter Season:

Per ton of cargo	fr. 0.724	for the entire distance
" " " capacity	" 0.270	" " " "
" " " " returning empty	" 0.306	" " " "

Summer Season:

Per ton of cargo	fr. 0.683	for the entire distance
" " " capacity	" 0.270	" " " "
" " " " returning empty	" 0.306	" " " "

General observations. — Loaded boats to which the tariffs nos 2, 3, 4, 5 and 6 are applied are drawn along the canal by horses and towed on the Dendre at the charge of the company.

The same rule will be applied to loaded boats only making a partial journey on the canal and navigating under article 2 of tariff A no. 1.

It is understood that boatmen on board of boats carrying a cargo less than the tonnage of capacity shall pay:

1. traction dues for the cargo as it is;
2. " " " " ton of capacity forming the difference between this cargo and the total capacity.

They may not demand to be towed or drawn without having previously paid the traction dues on the tonnage of capacity forming this difference.

Special traction tariffs.

Tariff no I Special. — For all intermediate destinations between Blaton and Termonde:

1. On the canal from Blaton to Ath both ways and at all seasons:

For all loaded boats.

Per ton of cargo	fr. 0.002	per	kilometre.
" " " capacity	" 0.002	"	"

2. On the canalised Sambre ascent in winter.

Per ton of cargo	fr. 0.0072	per	kilometre.
" " " capacity.	" 0.0020	"	"

For loaded boats in destination of Lessines.

Per ton of cargo	fr. 0.005561	"	"
" " " capacity.	" 0.002000	"	"

3. On the canalised Dendre Ascent Summer Season.

Per ton of cargo	fr. 0.0060	"	"
" " " capacity.	" 0.0020	"	"

For loaded boats in destination of Lessines.

Per ton of cargo	fr. 0.04361	"	"
" " " capacity.	" 0.002000	"	"

4. On the canalised Dendre descent. All season.

Per ton of cargo	fr. 0.0031	"	"
" " " capacity.	" 0.0020	"	"

5. On the canalised Dendre for ascent in all seasons:

For all boats loaded at the banks of Acren, Lessines and C. Houbain of wich the boatmen wish to employ means of traction on the whole length of the canal te supplement will be charged.

1st.	For Acren.	Per ton of cargo and per kilometre of the canal	fr. 0.00260;
2nd.	" Lessines.	" " " " " " " " "	" 0.00196;
3nd.	" C. Hubain.	" " " " " " " " "	" 0.00176;

Observation. — Loaded boats traversing the entire distance or the Dendre as well as those in destination to Ath or any point whatever of the canal pay traction dues according to tariff no. 2.

IV. INFLUENCE OF THE TONNAGE OF THE BOAT.

Generally speaking in Belgium and without exception on the State system the tonnage of the capacity of the boat is no longer taken into account in the fixing of navigation dues.

The law of February 19th 1860 applied at the same time the tonnage and the cargo as bases for the charging of dues. We have shown to what complicated calculations and anomalies this double basis led, and how already in 1865 the system being condemned by practice had been entirely abandoned on the State system. The system remains, however, still in force on the canals of Brussels and from Louvain to the Rupel, and on the conceded ways, viz. the l'Espierres, the canal from Blaton to Ath and the canalised Dendre. The application of a complicated tariff is more easily conceived on conceded ways than on those of the State, because on the one hand the traffic is more restricted and limited to short distances, and on the other hand the work of collection is performed by a special staff.

On the Dendre and on the canal from Blaton to Ath not only the tonnage, but even the draft of the boat, which is really only one of the

factors of the tonnage, is taken into account to modify the amount of the dues in the measure hereafter indicated.

Draft of boats. — Loaded boats traversing the waterway either the entire distance or only partially in both directions and having a draft of 1.50 m. up to 1.80 m. or more pay for their capacity the same tonnage as for their cargo.

Boats loaded to 1.50 m. and under up to 35 tons pay for their capacity a tonnage corresponding to a draft of m. 1,50 and the cargo such as it is.

Boats loaded with less than 35 tons pay for their capacity a tonnage corresponding to a draft of 1.80 m. and the cargo such as it is.

For returning empty is collected the tonnage of the capacity and a draft of 1.80 m.

Influence of the nature and value and quantity of the merchandise transported Classification of merchandise.

Equally with the double basis, the classing of merchandise with the view of tarification has been long since abandoned on the State system for two motives, viz. too great and useless complication, considering that transports by water are for the greatest part, not to say nearly totally, heavy transports.

There is now no trace left of the differential tariffs according to the nature and value of the merchandise, except on the canal from Brussels to the Rupel and on the l'Espierres canal, and the number of classes is exceedingly reduced, as is shown in the tables of the first chapter in which are given the subdivisions in which different products were divided.

The quantity of merchandise transported, that is, the cargo tonnage of the boat is one of the two factors, which serve to determine the amount of the tolls; the other factor is the distance traversed.

V. EXEMPTION FROM OR REBATEMENT OF TOLLS.

On the navigable ways administered by the State exemption from navigation dues is granted by the general regulations of police and navigation approved by the royal decree of May 1st 1889. Art. 82:

1. To all vessels belonging to the army or serving for its operations or transports, as well as to all other State vessels navigating under the national flag;

2. To tenders empty or loaded of vessels obliged to discharge a part of their cargo on account of a reduction of the regulation draft of water or for any other accidental cause, such as average etc.;

The tolls are due on the total of the cargo of the vessel before it is discharged;

3. To vessels employed by the service of the navigable ways, and put in movement on a written order of an agent of the administration;

4. To craft with a tonnage less than three tons;

5. To towing boats and ice-breakers;

6. To vessels which at time of rising or falling tide are displaced by order of the administration and return to their point of departure when

the cause which necessitated their displacement has ceased to exist;

7. To boats loaded exclusively with manure; matters which are considered as such, and are thus exempt from transport dues are at the present day many in number and are enumerated in the Royal decree of October 6th 1890.

Reduction of tolls is also accorded to boats doing a regular service. Thus, boats which are exclusively employed in a regular passenger service and carry only passengers and their luggage are subjected only to a quarter of the tax due in proportion to the complete cargo they are able to carry.

If they carry passengers and merchandise the dues are paid at the rate of three eighths of the complete cargo.

If they do a regular service for the transport of merchandise the dues are payable on three quarters of their complete cargo.

As we have already said, masters of empty boats need only provide themselves by a payment of 20 centimes with a permit to travel empty. This permit is available for the journey to the destination; a new permit is necessary for the return journey if the boat is still empty.

As indicated on pages 4 and 5 reductions of toll are granted to boats travelling empty on the communal canals from Brussels to the Rupel and from Louvain to the Dyle as well as on the conceded navigable ways.

The tables inserted in the first chapter show, also, that considerable reductions of tolls are granted to empty boats on communal canals and conceded ways.

On the canal from Blaton to Ath and on the conceded Dendre the regulation reductions are as follows:

Reductions. — The matters considered as manure are not allowed any reduction, but pay the same tariffs as other products. — Nevertheless, exception is made for boats laden with lime for manure, viz.:

1st. Those coming from Blaton in destination for places situated between Alost and Termonde (not including Alost) and

2nd. Those coming from the basin of Tournai for Alost which pay the rates of tariff no. 3.

3nd. Those, coming from the basin of Tournai for destinations between Alost and Termonde pay the rates of tariff no. 4.

Finally, boats loaded with fecal matter entering at Blaton for the entire distance pay the rates of tariff no. 3.

It should be remarked that merchandise destined for exportation, as well as merchandise imported from abroad by maritime way, enjoys special favours. Thus on the canal from Ghent to Terneuzen and on the canal fron Ghent to Ostend „boats coming from the sea and vice-versa and those which without coming from the sea are employed in the transport of cargo from such boats, are exempt from navigation dues and the permit for travelling empty". (1)

By an analogous arrangement on the canal from Brussels to the Rupel (2)

---

(1) P. 75 Guide du batelier, réglements particuliers.

(2) Royal decree of March 25th 1882.

a reduction of 50 % on navigation dues is granted for every steam or sailing vessel doing a regular service between Brussels and any foreign place and carrying merchandise from the interior for exportation. The same reduction is granted on the return of the same ships bringing merchandise from abroad for the interior or in transit.

VI. MODE OF COLLECTION. — CONTROL.

All along the navigable ways administered by the State the navigation dues are collected by agents who are ordinarily at the same time lockkeepers and collectors.

On one and the same line payment is made at the office of the place of departure, or from office to office.

The real cargo of the boat is determined from the indications given in the gauging manifest (*proces verbal de jaugeage*)and from the standards with which every boat should be provided. The distance is determined by the tables of distances annexed to the regulation of navigable ways.

The guaging of the boats is effected by following an elementary and practical method, which without aiming at an extraordinary and entirely mathematical decision of the useful capacity of the boat, is the more satisfactory as the unitary rates have now become very reduced and that a slight error of volume is thus not of great importance.

The method is simple and rapid; these are two essential qualities and it is sufficiently exact, as may be judged from Annex II (1).

The gauging manifest is signed by the gauging expert and by the boatman. It is examined by the Chief Engineer of the service and by a Director of registration. With regard to collection control is exercised from lock to lock by reading the scales and the guaging manifest. The general regulations stipulate a series of clauses for intermediate distances between the collecting offices, for fractions of decimetres of draft, for cases of difference of water-line fore and aft, for the case of absence of gauging manifest, for loading and unloading in course of route, and finally for distance traversed beyond the extreme point mentioned in the declaration made at the point of departure. It would be too long and of no great interest to relate here how all these difficulties of detail have been overcome. However all these exceptional cases are enumerated in the general regulations which we have frequently mentioned.

VII. DUES FOR WORKING LOCKS, FLOODGATES AND BRIDGES.

The only ways which still levy bridge dues and tolls for passage are the communal canals of East Flanders; it is necessary to add two small

(1) Royal decree of March 25th 1882.

canals in West Flanders, the Blankenberg canal, administered by a company of Wateringues, which levies a toll for passage at the Speyelock, and the Martje canal, administered by third parties, who levy a toll at the passage of the Merkem bridge. At Termonde the communal administration levies rates on the Dendre at the Bogards and Augustins bridges. The legality of these taxes is questioned by the State. Finally there exists on the Dyle a toll for passage at the Moulins floodgates sanctioned by a decree of 1819. This tax will soon disappear and at the same time the work itself. Everywhere else local taxes for manœuvres have been suppressed.

VIII. SUPPLEMENTARY DUES AT NIGHT.

Navigation at night is not yet practised in a regular manner on all the ways of the State system. It is simply tolerated on several canals and gives occasion for special dues which are not handed in to the State, but which serve to compensate the staff performing this supplementary labour.

These dues, paid at the passing of constructive works, amount to 75 centimes for each lock-keeper and 50 centimes for each bridge-man or assistant lock-keeper.

IX. QUAY DUES.

In conclusion, and in order that we may omit nothing concerning tolls collected on canals and rivers, we must say a word respecting the quay dues which are collected in inland navigation ports.

These ports are subdivided into three categories, those established by the State, those constructed by communes entirely at their own expense, and finally, and these are the most numerous, those executed by the aid of a subvention from the Public Treasury.

The State does not collect any tax in inland navigation ports, which it has established at its own expense; it provides for expenses of maintainance, takes no part in the administration, and does not require repayment either of the expenses of maintainance nor interest on the cost of the first establisment.

The communes on the contrary endeavour to obtain a return of their outlay, and they are authorised to do so by the Government; but as a rule at the present time they cannot make any profit by the administration of the quays.

The tariffs of quay dues are consequently in each particular case arranged in such manner that the receipts do not exceed the total of ordinary and extraordinary expenses caused by these quays. The receipts and expenses connected with these works are the subject of a special account. This

account is presented to the superior administration at the end of each year. At the commencement of the working and during the first three years the tariff is only provisional and it is revised, if there is cause for this to be done, in the course of the third year, in order to place the receipts in harmony with the expenses.

The public quays constructed by the State are for the use of all, without favour or exception, and without any other restriction for the users than that the latter conform to the regulations of navigation, and to those of the local police.

Translated by G. J. ROWLAND.

Annex No. I.

TOLLS.

Brief review of the modifications applied to bases and modes of collection of tolls in Belgium.

DESIGNATION OF THE NAVIGABLE WAYS.	HISTORICAL.
Canal from Charleroi to Brussels. Commenced March, 15th 1827. Opened to Navigation September 22nd 1832. Repurchased by the State by virtue of the law of June, 1st 1839.	Royal decree of September 17th 1832. — Fixed and uniform tax of fl. 1.45 per ton from Charleroi or from the Centre to Brussels and vice versa. Royal decree of June 28th 1833. — Reduction of 16 p.c. of the preceding tax. Royal decree of March 31st 1849. — Reduction of 35 p.c. of the tax of 1833. Law of February 19th 1860 and Royal decree of February the 20th following. — Radical modification of the system of tolls previously in use. The dues are fixed per league of 5000 m. and per ton of cargo and capacity in the following manner: francs. Per ton of cargo . . . . 0.0480 Per ton of capacity of the vessel . . . . 0.0160 ditto ditto (returning empty) . . . . 0.0160 Total 0.0800 Law of July 1st 1865 and Royal decree of July 26th following. — Modification of the basis of the law, and of the Royal decree of 1860. — The tax is fixed at fr. 0.01 per ton of cargo per kilometre. Royal decree of June 1st 1886. — Reduction of the tax from fr. 0.01 to fr. 0.005.
Canal from Ghent to Terneuzen. Commenced January 24th 1825. Opened to Navigation November 18th 1827. Constructed by the State.	Royal decree of April 9th 1830. — Sea-going vessels: For the whole length of traverse fl. 0.48 to fl. 0.38 per sea-ton (according to the direction and season of the year); bridge-tax fl. 0.20. Inland boats: fl. 0.20 to fl. 0.35; bridge-tax fl 0.10. Treaty of April 19th 1839. — Sole tax for sea-going vessels, ascending fl. 2.3704 per ton; for those descending fl. 0.38. Treaty of November 5th 1842. — Suppression of all taxes on maritime navigation. Suppression of the bridge-tax and reduction by $^1/_3$ of the taxes charged on inland navigation. Royal decree of February 17th 1852. — Reduction of 50 p.c. of the previous tariff. Royal decree of June 5th 1871. — Putting in execution of the law of July 1st 1865 (see above the canal from Charleroi to Brussels.) — Tax of fr. 0.005 per ton of cargo per kilometre.
Canal from Pommeroeul to Antoing. Commenced June 19th 1823.	Royal decree of July 27th 1827. — Fixed and uniform tax of fr. 0.596 per ton of capacity and fr. 1.285 per ton of cargo. Royal decree of January 9th 1831. — Reduction of 50 p.c. of the previous tariff. Royal decree of April 15th 1834. — The tax is fixed at fr. 0.1481 per ton of capacity and fr. 0.444 per ton of cargo.

DESIGNATION OF THE NAVIGABLE WAYS.	HISTORICAL.
Opened to Navigation June 26th 1826. Repurchased by the State by virtue of the Royal decree of June 9th 1828.	Royal decree of March 13th 1852. — Reduction of 60 p.c. of the tariff of 1834. Royal decree of September 2nd 1863. — Putting in execution the law of February 19th 1860 (Charleroi to Brussels). — The taxes are fixed per league of 5000 metres per ton of cargo and capacity in the following manner: francs. Per ton of cargo . . . . 0.03 Per ton of capacity of the vessel . . . . 0.01 ditto (returning empty) . . . . 0.01 Total . . 0.05 Royal decree of July 26th 1865, putting in execution of the law of July 1st 1865 (Charleroi to Brussels). The tax is fixed at fr. 0.01 per ton of cargo per kilometre. Royal decree of June 1st 1886. — Reduction of this tax to fr. 0.005.
Canal from Maestricht to Bois-le-Duc (Belgian part). Commenced June 19th 1822. Opened to Navigation August 24th 1826. Constructed by the State.	Royal decree of October 3rd 1828. — Loaded boats fl. 0.025 per ton and per league from Maestricht to Bois-le-Duc; fl. 0.045 in reverse direction. Empty boats: half. Royal decree of October 12th 1839 and July 9th 1842. — The preceding tariff is modified as follows: From Loozen to Hocht fl. 0.9015; from Hocht to Bocholt fl. 0.451. Treaty of November 5th 1842. — Reduction of the preceding taxes, respectively, to fl. 0.4265 and fl. 0.2845. Treaty of July 9th 1846. — The taxes are fixed per ton per league in the following mauner. Loaded boats: fr. 0.03175; empty boats fr. 0.01587. Treaty of March 15th 1852. — Reduction by 50 p.c. of the preceding taxes. Royal decree of May 3rd 1880, putting in execution of the law of July, 1st 1865. (Charleroi to Brussels). Tax of fr. 0.0025 per ton of cargo and per kilometre.
Canal from Liége to Maestricht (Belgian part). Commenced March 4th 1846. Opened to Navigation October 21st 1850. Constructed by the State.	Royal decree of September 1st 1850. — The taxes are fixed per ton of capacity per league as follows: Loaded boats: fr. 0.10; empty boats fr. 0.05. Royal decree of February 20th 1860, putting in execution of the law of February 19th 1860 (Charleroi to Brussels). The taxes are fixed per league of 5000 meters per ton of cargo and of capacity as follows: francs. Per ton of cargo . . . . 0.0450 Per ton of capacity of the boat. . . . 0.0150 ditto (returning empty) . . . 0.0150 Total . . . 0.0750

DESIGNATION OF THE NAVIGABLE WAYS.	HISTORICAL.
	Royal decree of October 24th 1860. — The above taxes are reduced respectively to fr. 0.03, fr. 0.01 and fr. 0.01, in all fr. 0.05. Royal decree of July 26th 1865, putting in execution of the law of July 1st 1865 (Charleroi canal to Brussels). — The tax is fixed at fr. 0.0075 per ton of cargo per kilometre. Royal decree of June 1st 1886. — Reduction of the preceding tax to fr. 0.005.
Junction Canal from the Meuse to the Scheldt. Commenced April 3rd 1843. Opened to Navigation September 22nd 1846 (on all its length). Constructed by the State.	Royal decree of November 23rd 1844. — The taxes for the 1st Section of the canal are fixed as follows: Per ton of cargo per league fr. 0.05 for straws, hay, pitch-pine, trees, poles, fire-wood and faggots; fr. 0.10 for pit-coal, stones and other merchandise not mentioned above. (This tariff has been made applicable to the two other sections of the canal by the Royal decrees of October 12th and September 28th 1856). Royal decree of February 20th 1860 putting in execution the law of February 19th 1860 (Charleroi to Brussels). — For the 3 sections, the taxes are fixed per league of 5000 metres per ton of cargo and of capacity as follows: francs. Per ton of cargo . . . . 0.03 Per ton of capacity of the boat . . . . . . 0.01 ditto (returning empty) . . . . . 0.01 Total . . . . . 0.05 Royal decree of July 26th 1865 putting into execution of the law of July 1st 1865 (from Charleroi to Brussels). The tax is fixed at fr. 0.0075 per ton of cargo per kilometre. Royal decree of June 1st 1886. — Reduction of the preceding tax to fr. 0.005.
Canal from Mons to Condé (Belgian part). Commenced October 18th 1807. Opened to Navigation October 19th 1818. Constructed by the State; ceded to the Province by decree of December 17th 1819; retaken	Royal decree of December 14th 1815. — Provisional rates of fr. 0.02 per ton per league for loaded boats, and fr. 0.01 for empty boats. Royal decree of August 1822. — Augmentation by 50 p.c. of the preceding rates. Royal decree of July 27th 1827. — Rates payable to each of the four offices fl. 0.07 per 10 tons of capacity and fl. 0.07 per 10 tons of cargo. Royal decree of April 15th 1834. — The preceding tax is fixed at fr. 0.14. Royal decree of December 2nd 1839. — The rate is fixed at fr. 0.05 per ton of cargo to be paid at each of the offices. Royal decree of September 2nd 1863, putting in execution the law of February the 19th 1860 (Charleroi te Brussels). The rates are fixed per league of 5000 meters and per ton of cargo and of capacity as follows:

DESIGNATION OF THE NAVIGABLE WAYS.	HISTORICAL.
by virtue of the law of December 30th 1843.	Per ton of cargo . . . . francs 0.03 Per ton of capacity . . . . 0.01 ditto (returning empty) . . . 0.01 Total . . 0.05 Royal decree of July 26th 1865, putting in execution the law of July 1st 1865 (Charleroi to Brussels). The rate is fixed at fr. 0.01 per ton of cargo per kilometre. Royal decree of June 1st 1886. — Reduction of the preceding tax fr. 0.005.
Upper-Scheldt. Canalisation not completed. Retaken by the State by virtue of the budget of December 31st 1838.	Royal decree of August 16th 1822, put in force January 1st 1823 and indefinitely maintained by decree of November 16th 1824. Part situated in Hainault. Dues levied at the locks at Antoing and at the Trous bridge at Tournay, varying according to the capacity of the boats and divided into 9 classes. Rate per ton of: francs. Empty boats . . . . 0.01 ditto half loaded . . . . 0.015 ditto descending more than half loaded. . . . . 0.02 Royal decree of December 13th 1819. — Part situated in East Flanders. — Rate of fr. 0.0325 per ton of capacity at each of the bars of Espierres, of Autryve, of Audenarde and of Semmerzaeke; Rate of fr. 0.0125 at the Madon bridge and of fr. 0.850 at the locks de la Pêcherie at Ghent. Royal decree of March 13th 1852. — Reduction by 50 pct. of the preceding tariffs. Royal decree of June 23rd 1886. — The navigation dues are fixed, in consequence of the royal decree of June 1st (same year) uniformly and on all the length of the river at fr. 0.0016 per ton of cargo per kilometre.
Lys. Retaken by the State in virtue of the budget of December 31st 1838.	Royal decree of September 30th 1839. — Part situated in West Flanders. — The rates are fixed per ton of capacity and are payable on passing the offices, according to the following tariff: francs. francs. Toll of Comines . . . . loaded 0.0635 empty 0.0212 „ „ Menin . . . . . ditto 0.0635 ditto 0.0212 „ „ Harlebeke. . . . ditto 0.1058 ditto 0.0635 „ „ Vive St. Eloi . . ditto 0.0635 ditto 0.0212 Royal decree of November 20th 1833. — Part situated in East Flanders. — Tax of fr. 0.0425 per ton of capacity payable at the locks of la Pêcherie at Ghent. Royal decree of April 20th 1863. — Putting in execution of the law of February 19th 1860. (Charleroi to Brussels). The taxes

DESIGNATION OF THE NAVIGABLE WAYS.	HISTORICAL.
	are fixed per league of 5000 metres and per ton of cargo and of capacity, as follows:

	francs.
Per ton of cargo	0.012
Per ton of capacity of the boat	0.004
ditto (returning empty)	0.004
Total	0.020

Royal decree of July 26th 1865. — Putting in execution of the law of July 1st 1865 (from Charleroi to Brussels). — The tax is fixed at fr. 0.002 per ton of cargo and per kilometre.

Royal decree of May 7th 1867. — Reduction of the preceding tax to fr. 0.0012.

Royal decree of June 1st 1886. — Fixing of the dues of 1867 at fr. 0.0016 (with a view to uniformity).

Meuse (Belgian part).

Retaken by the State in virtue of the budget of December 31st 1838.

Canalised from 1860 to 1880.

Royal decree of October 30th 1820. — The tax is payable on passing the offices; it is fl. 0.03 per ton of capacity or cubic m. of the Netherlands, for loaded boats and half for empty boats. Regulation of May 20th 1843. — Putting in execution of the treaty of April 19th 1839 and of November 5th 1842. — The tax due on passing the offices is fixed at fr. 0.008 per cubic metre of capacity of the boat per league of 5 kilometres, for loaded boats, and half for empty boats.

Royal decree of January 6th 1870. — Reduction of this tax for boats furnished with a scale of dimensions. For boats of which the cargo does not exceed half the tonnage, the tax reduced to fr. 0.004 is levied on this half and the entire tax of fr. 0.008 on the other half; in the contrary case the toll of fr. 0.008 is levied on the total of the tonnage.

Convention of October 31st 1885. — The tax of navigation is fixed at fr. 0.0016 per ton of cargo per kilometre.

Sambre (Belgian part).

Canalised from 1824 to 1828.

Opened to Navigation January 1st 1829.

Repurchased by the State according to an arrangement sanctioned by the law of September 26th 1835.

Royal decree of October 13th 1832. — The tax is fixed at fixed at fl. 0.09 per ton and per league.

Royal decree of September 1st 1840, November 1st 1849, September 22nd 1852, April 5th and October 24th 1854. — Reductions of this tax for pit-coals and various other materials.

Royal decree of September 26th 1855. — Uniform tax, for all sorts of merchandise, of fr. 0.06 per ton per league.

Royal decree of July 26th 1865. — Putting in execution of the law of July 1st 1865 (Charleroi to Brussels). — The tax is fixed at fr. 0.0075 per ton of cargo per kilometre.

Royal decree of July 1st 1886. — Reduction of this tax to fr. 0.004.

DESIGNATION OF THE NAVIGABLE WAYS.	HISTORICAL.
Dendre. Conceded to the Provinces by decree of December 17th 1819. Taken back by the budgetary law February 18th 1840. Canalised by the State and conceded by virtue of the law of September 8th 1859, by Royal decree of January 8th 1863.	Royal decree of August 25th 1887. — Reduction of the preceding tax to fr. 0.0016. Royal decree of August 13th 1822. — Part situated in Hainault: The tax is fixed per ton, as follows: Office of Lessines: Direction from Lessines to Ath and vice-versa; fully loaded fr. 0.06, half loaded fr. 0.045, empty fr. 0.01. Direction from Lessines to Grammont and vice-versa: fr. 0.02, fr. 0.105, and fr. 0.01 as above. Royal decree of December 13th 1829. — Part situated in East Flanders. — The tax is fixed at fr. 0.0175 per ton of the boat loaded or empty payable before each of the 7 offices. Royal decree of October 5th 1868. — The taxes are uniformly fixed for the whole length of the river, as follows: francs. Per ton of cargo per kilometre . . . . . 0.006 ditto capacity ditto . . . 0.002 ditto (returning empty) . . . 0.002 Total 0.010

Annex No. II.

MODE OF GAUGING BOATS.

Total tonnage. — To arrive at a knowledge of the weight of the complete cargo of a boat, we take four horizontal sections of the vessel, the first at the water-line when empty, the second 50 centimetres higher, the third at one metre above the water-line, and the fourth coincident with the plane of the highest water-line.

Between these planes of immersion when empty, and when fully laden the boat is thus divided into three sections, of which the sum of the volumes represents the number of cubic metres of water displaced by the full cargo of the boat, that is, the maximum number of tons of 1000 kilogrammes which it can carry.

The volume of each section is easily obtained by calculating the area of the two limiting sections above and below the section considered, and in multiplying the half of the sum of these areas by the height which separates them.

The following formulæ serve to make the calculations in question:

The area of the 1st section equals:

$$\frac{a_1 + 2b_1 + c_1}{4} \times l_1 + \frac{c_1 + 2d_1 + 2e_1 + 2f_1 + g_1}{8} \times L_1 + \frac{g_1 + 2h_1 + i_1}{4} \times l'_1 = A_1.$$

The area of the 2nd section equals:

$$\frac{a_2 + 2b_2 + c_2}{4} \times l_2 + \frac{c_2 + 2d_2 + 2e_2 + 2f_2 + g_2}{8} \times L_2 + \frac{g_2 + 2h_2 + i_2}{4} \times l_2 = A_2.$$

The area of the 3nd section equals:

$$\frac{a_3 + 2b_3 + c_3}{4} \times l_3 + \frac{c_3 + 2d_3 + 2e_3 + 2f_3 + g_3}{8} \times L_3 + \frac{g_3 + 2h_3 + i_3}{3} \times l'_3 = A_3.$$

And the area of the 4th section equals:

$$\frac{a_4 + 2b_4 + c_4}{4} \times l_4 + \frac{c_4 + 2d_4 + 2e_4 + 2f_4 + g_4}{8} \times L_4 + \frac{g_4 + 2h_4 + i_4}{4} \times l'_4 = A_4.$$

From these surfaces we deduce the cubes:

1st of the lower section:

$$\frac{A_1 + A_2}{2} \times 0.50 \text{ m.} = V_1;$$

2nd of the intermedial section:

$$\frac{A_2 + A_3}{2} \times 0.50 \text{ m.} = V_2;$$

3nd of the upper section:

$$\frac{A_3 + A_4}{2} \times (H - 1.00 \text{ m.}) = V_3.$$

The sum of the cubes $V_1 + V_2 + V_3 = T$ or the total tonnage of the boat.

In the gauge manifest the letters of the formulæ and of the sections are replaced by the corresponding figures.

The widths such as *b* and *h* are taken at mid distance between the widths *a* and *c*, *g* and *i*.

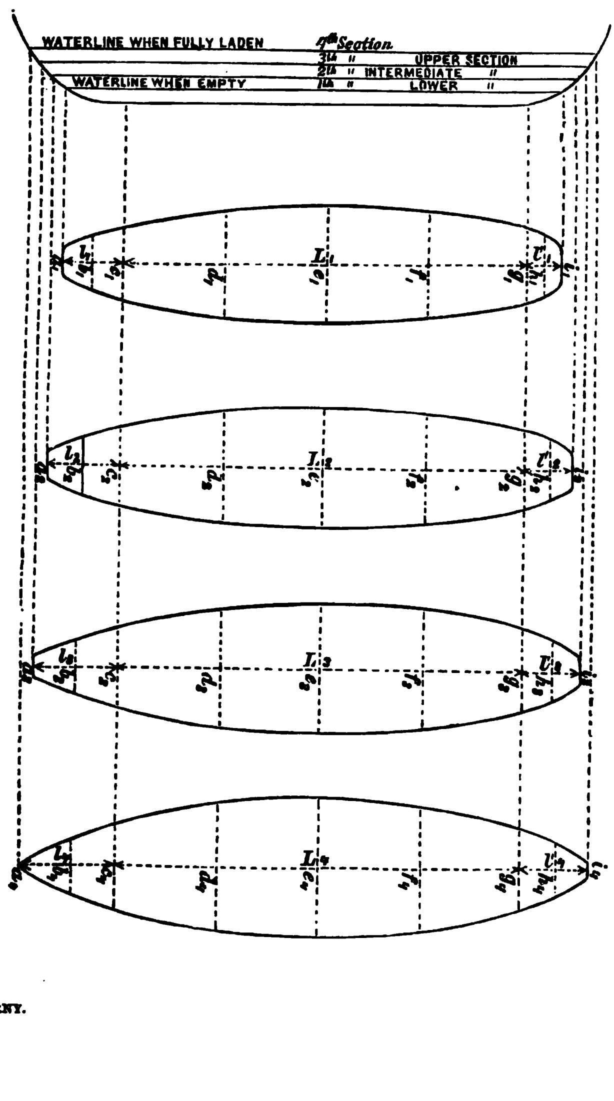
The widths *c*, *d*, *e*, *f*, *g* are equidistant.

Progressive tonnage. — The progressive tonnage of the boat at intervals of 5 centimetres in calculated as follows from the draft when empty to the draft when fully laden:

Lower section. — From nought to the total volume of this section the volume increases every 5 centimetres by a fraction equal to $\frac{1}{10}$ of the volume of the section.

Intermediate section. — From the volume of the lower section to the volume of the two sections united the volume increases every 5 centimetres by a fraction equal to $\frac{1}{10}$ of the volume of the intermediate section.

Upper section. — In this section the volume increases every 5 centimetres by a fraction equal to the $\frac{1}{n}$ of the volume of the said section (n representing the number of times 5 centimetres is contained in the height of the third section).



18

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

5th QUESTION.

TOLLS ON NAVIGABLE WAYS

in FRANCE.

REPORT

BY

MAURICE RENAUD,
Ingénieur des Ponts et Chaussées à Paris.

THE HAGUE,
Printed by Belinfante B^{ths}, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.
1894.

VI^th International Inland Navigation Congress.

THE HAGUE, 1894.

Tolls on Navigable Ways in France.

REPORT

BY

MAURICE RENAUD,

Ingénieur des Ponts et Chaussées à Paris.

I. — INTRODUCTION AND DIVISION OF THE REPORT.

In France nearly all (93 %) of the system of navigable ways is in the hands of the State, and is worked and administered by it.

The laws of December 21st 1879 and February 19th 1880 suppressed all navigation dues on these ways, and at the present time only a few customary tolls are levied.

Tolls, therefore, only exist on that portion of the system, which has been made the object of concessions still in force, viz., the following:

Perpetual concessions.

	Kilometres.
Rivers.	
The canalised Lez or Grave canal	10
Canals.	
Lunel	9
Midi	279
Ourcq, St. Denis and St. Martin (*belonging to the city of Paris*)	120

Temporary concessions.

Canals.	Kilometres.	Expiration of the Concessions.
Furnes to Dunkirk	13	1899
Dive	40	1925
From the Sambre to the Oise	71	1937
Bourgidon (Branch of the canal from the Rhône to Cette)	11	1939
Sylvéréal (ditto)	9	1939
Vassy to St. Dizier	23	1948
Beuvry (Branch of the Aire canal)	3	1950
Canalised Souchez (Part of the canal from Lens to the Deulle)	3	1950
Garonne Lateral	213	1960

In replying to the fifth question of the programme of the work of the Congress we think it will be useful to point out what were the tolls levied on the State system of navigable ways before 1880, and what was the mode of collection and control employed.

With regard to the conceded ways, we will select the principal ones amongst them and briefly study them from this point of view.

For this purpose we have selected the following:

1th The Midi Canal and the Garonne Lateral Canal (administered by the same Company).

2nd The Canals of the city of Paris.

3rd The Canal from the Sambre to the Oise.

4th The Canal from Vassy to St. Dizier.

We will give later on the general conclusions which we find to result from the study of this subject.

II. — TOLLS LEVIED ON THE STATE SYSTEM OF NAVIGABLE WAYS before 1880.

The rates of navigation dues levied before 1880 on navigable canals and rivers administered by the State had been fixed in the most recent case by an Imperial decree of 19th of February 1867.

The rate was per ton per kilometre.

The navigable ways were divided in two categories:

1. Rivers and canals assimilated to rivers.
2. Canals and rivers assimilated to canals.

A table annexed to the decree indicated for every navigable way the category in which it should be included.

For the collection of the rates merchandise was divided in two classes.

The first class comprised generally wines, cereals, colonial wares, worked metals, textile fabrics, provisions etc.

The second class unworked metals, combustibles, wood, minerals etc. and all objects not mentioned in the first class.

The tariffs were as follows:

	Per ton per kilometre. 1st Category.	2nd Category.
1st class	f 0.002 (two millimes)	f 0.005. (five millimes)
2nd class	f 0.001 (one millime)	f 0.002 (two millimes)

For wood-floats and rafts there was a special tariff, by which they paid by cubic metre, per ton per kilometre:

1st Category.	2nd Category.
f 0.0002.	f 0.002.

Empty boats were exempt from all toll; and there were no supplementary dues demanded for navigation at night.

Before entering on the question of the mode of collection it is necessary to remark that in France all boats travelling on the navigable ways were gauged and are still gauged according to the decree of November 17th 1880.

No boat is allowed to travel unless it has first been gauged and furnished with a certificate.

This certificate declares:

1st. The name or divice of the boat.

2nd. The name and place of residence of the owner.

3rd. The exterior dimensions of the boat.

4th. The draft of water when fully loaded.

5th. The draft of water when empty but with the rigging.

6th. The tonnage of the boat when fully loaded and the tonnage per centimetre of immersion.

On each side of the boat is affixed a copper scale graduated in centimetres. The zero of the scale corresponds to the draft of water when the boat is empty and a mark placed higher up indicates the floating line when completely loaded.

On iron boats the scale may be simply painted on the hull, on condition that it be on a part that is absolutely fixed.

Bargemen are forbidden to remove these scales, and, moreover, the agents of the administration of Bridges and Ways may at any time of the year proceed to a verification of the gauge.

In addition, every person in charge of a boat or float must be provided on every journey with a declaration specifying the nature and weight of the merchandise he is transporting, all loading or unloading, which has been effected on the route as well as the points of departure and of destination.

In connection with the collection of dues the importance of this gauging certificate required from boatmen in France will be easily understood.

The collector is not obliged to rely on the bargemen's declaration, nor to take the gauge in every case.

The immersion of the scales gives the tonnage and the reading of these scales at different points of the route is sufficient for the control.

These explanations given we return to te mode of collection and control in use on the navigable system of the State before 1880.

The collection of dues was effected by a service absolutely distinct from and independent of that of the maintainance, viz., the service for the collection of indirect taxes administered by the Minister of Finance.

Collecting offices were established at the principal ports which served at the same time for collecting and for control.

All boats travelling on the system, whether empty or loaded, liable to dues or exempt, had to be provided with a document showing that they had made at one of the collecting offices the declaration required by the law and this document had to be produced whenever it was demanded.

This document, as we shall see further on, was entitled a pass (*laissez-passer*) or provisional receipt, (acquit à caution) according as the boats were liable to duty, or were empty boats, or exempted from duty, employed in the work of repair and maintainance, boats belonging to the State etc. and thus requiring only a pass.

Those in charge of the boats were not obliged to pay at the time of departure. This could be done either at the place of departure, in the course of the journey, or at the place of destination.

In the first case a pass with a receipt was handed to the boatman. This document contained all particulars concerning the cargo, the places of departure and destination and had to be controlled at all the collecting offices passed on the journey and delivered up to the office at the place of destination.

In the second case the bargeman received a pass without a receipt; this had to be controlled at the first office reached, and payment made for the distance traversed, for which a receipt was given. He could then continue his journey until another collecting office was reached, where the same formalities had to be again observed and so on from office to office until the destination was reached where the pass was given up and payment of the last dues made.

In the third case the boatman took a provisional receipt (acquit à caution) containing all particulars required by the control, the tonnage, nature of the merchandise, places of departure and destination, and which was controlled at all the offices passed on the way and delivered up at the office of destination where the dues were paid.

The first and the third cases especially occurred when boats transported a complete cargo from one point to another, and the second when partial loading or unloading was effected in the course of the journey.

We must add that when any embarcation was effected in a port where no collecting office existed the boatman had to provide himself with a provisional pass, which he obtained at the nearest office; he took this

pass at the first office he reached on his journey and it was further regulated as explained above.

Control was exercised at the collecting offices by the presentation and examination of the pass or receipt, and at any part of the journey in the same way; these documents could be inspected by any agent of the administration of indirect taxes and even by the lock-keepers.

The general control was administered in the following way:

The pass or provisional receipt was taken out of a register in which was retained a corresponding *coupon*; it might be obtained at any office and had to be delivered up at the office of destination, or at one of the offices in the course of the route, and there attached to the *coupon* of the receipt delivered. A clerk checked these documents, and comparing them with their *coupons* made certain that every delivery of a pass or provisional receipt effected in one office corresponded to a receipt in another.

It will be seen that this system was somewhat complicated. There was no permanent control at the places of departure and destination except when the loading or unloading took place in a port where there was a collecting office.

In other cases the only means of guidance were the bill of lading and the declaration of the boatman, and these declarations were only checked by a roving control. It is thus clear that transports effected between two offices might easily escape all payment of dues.

III. THE MIDI CANAL AND THE GARONNE LATERAL CANAL.

The Midi Canal begins below Toulouse, where it communicates with the Garonne, and the Garonne Lateral Canal, and finds its issue in the lake of Thau. Its length including the junction canal and the outlet of Narbonne is 279 kilometres. The difference of water-level is regulated by 65 locks on the principal line, 17 of which are on the Atlantic side, and 48 on the side of the Mediterranean. The canal company holds a perpetual concession. This company has, however, sub-led the working of the canal for an annual payment to the „Compagnie des chemins de fer du Midi".

The Garonne Lateral Canal is a continuation of the Midi Canal; its length including the Brienne canal, the Montauban branch, the feeding canal at Agen, and the falls in the Tarn and the Baise is 213 kilometres.

It was conceded to the „Compagnie des chemins de fer du Midi" in virtue of the law of July 25th 1852 by a decree of August 4th of the same year. A new decree on August 1st 1857 prolonged the original concession in such a manner that the concession does not expire before December the 31st 1960.

The general tariffs of navigation dues on the Midi Canal are fixed per ton per distance of 5 kilometres.

They comprise 6 articles relating:

1st to travellers divided into two classes.

2nd to cattle also divided into two classes.

3rd to rafts comprising two classes.

4th to fish-boxes.

5th to empty boats divided into four classes.

6th to merchandise divided into five classes.

The table of tariffs gives the complete nomenclature of the merchandise included in each class which is too long and useless to enumerate.

We will give some idea of the classification in naming the principal objects of each class.

The first class comprises articles of luxury, Paris goods, cabinet-work, Rouen haberdashery, fresh vegetables, wines in hampers and in bottles, etc.

The second class alimentary and colonial wares, oats, corn, maize, wine in casks, hardware, machines, instruments used in husbandry, etc., etc.

The third class timber, railway sleepers, manure, rough castings, iron rails, etc.

The fourth class slates, tiles, bricks, lime, cement, hewn stone, fire-wood, etc.

The fifth class pit-coal, mill-stones, lime and sand-stone, broken stone, sand, earth and fecal matter, etc.

We will give the tariffs concerning merchandise as these are the only ones of real interest. They are as follows:

	Per ton per distance of 5 kilometres:
For the 1st class	30 centimes.
" " 2nd "	25 "
" " 3rd "	20 "
" " 4th "	15 "
" " 5th "	10 "

It is stipulated that the navigation dues on each distance of five kilometres shall be paid in full for every fraction of that distance traversed.

On the Garonne Lateral Canal the general tariffs are per ton per kilometre. These general tariffs comprise seven articles relating to the following objects:

The first to travellers divided into two classes.

The second to cattle comprising four classes.

The third to merchandise divided into two classes.

The fourth to wood-floats.

The fifth to fish-boxes.

The sixth to casks and barrels of every capacity each one separately.

The seventh to empty boats.

With respect to merchandise it will be sufficient to say without going into details of the nomenclature that the first class corresponds nearly

to the first three classes of the Midi Canal, and the second to the last two of that line.

On the Garonne Lateral Canal the tariffs are different accordingly as the transport is effected ascending or descending.

For merchandise the tariff is as follows:

	Per ton per kilometre, Ascent.	Descent.
For merchandise of the 1st class	4 centimes.	3 centimes.
" " " " 2nd "	3 "	2 "

As already said empty boats enjoy a special tariff, which is as below:

	Midi Canal. Per distance of 5 kilometres.	Garonne Lateral Canal. Per kilometre. Ascending.	Descending.
Empty boats of 80 tons or more and pleasure boats . . . . , ...	50 centimes.	10 centimes.	4 centimes.
Empty boats of 20 tons and less than 80 . .	37½ "	7½ "	3 "
Empty boats of less than 20 tons . . .	25 "	5 "	2½ "

On these canals boats navigating at night pay at each lock a supplementary tax of 30 centimes whatever may be their tonnage or in whichever direction they may be proceeding.

In addition to these general tariffs there are on these navigable ways special tariffs applying to special kinds of merchandise and for fixed distances.

These special tariffs are 16 in number.

One of them applies to passenger boats on the canals and fixes a subscription of fr. 150 per month for one boat, and fr. 75 for each additional boat employed by the same contractor.

The others refer to the transport of certain kinds of marchandise and may be divided into four categories:

1st. Special tariffs conceded to certain kinds of merchandise between Cette and Bordeaux in both directions, and traversing the entire length of the two canals. They are 10 in number and apply to steel, iron, sleepers, wood, marble, salt, oats, corn, maize, hemp, oil-cake, chemical products etc.

The reductions made on the general tariff by these means vary from 15 to 60 °/o.

2nd. A special tariff for corn, rye, maize, combustibles, minerals, wrought and cast-iron used in the construction of railways, Norwegian wood going from a foreign port on the Mediterranean to a foreign port on the Atlantic.

This tariff is very low, the reduction being as much as 80 °/o.

3rd. Special tariff to certain kinds of merchandise going from any one

point on the canals to any other point. These tariffs are three in number, and apply to sorgho-stalks, anthracite coal, mud, manure, and timber-floats.

The reduction on the general tariff exceeds 60 %.

4th. Special tariff for certain kinds of merchandise between two fixed points of the canal. This tariff refers to boats descending the Garonne. The reduction made is about 30 %.

The dues are collected by means of 21 collecting offices, but this service has the assistance of all the staff attached to the maintainance of the canal.

When a boat commences its journey or enters the canal it receives from the agent, guard, lockkeeper or watchman of the district, a descriptive document comprehending all the elements necessary for the estimation of the amount of the dues, place of departure, nature of the merchandise, immersion of the scales etc. This document is sent by the agent who compiles it to the first collecting office which the bargeman will reach on his journey, the bargeman taking his own copy with him.

He has to produce this at the first office and receives there a bill of payment containing an account of the dues which he will have to pay at the place of destination. This account is made out according to his declarations and has to be controlled at every collecting office which the boat passes, as well as at all the locks and moveable bridges. Every one of these agents has to satisfy himself that no alteration has been made in the state of the cargo.

If in the course of the journey any supplementary dues have to be levied, such for instance, as for passing a lock at night, the fact is advised to the nearest collecting office by means of a report from the agent, who has witnessed the operation and a notification of the same is made on the bill of payment at the time of passing this office.

When any partial unloading or loading is effected in the course of the journey a descriptive report is immediately made out by the agent of the district in which it has occurred, and the nearest collecting office being advised this office notes the alteration on the bill of payment.

Such events may either be notified in a special report or inscribed on the bill of payment.

When the boat arrives at its destination or leaves the canal. the nearest collecting office is advised and on the production of the bill of payment, which it now withdraws, collects the amount of the dues and gives a receipt for the same to the bargeman.

Under these conditions it seems that a good control on the journey is assured, as no boatman can travel without a document, which must be produced whenever it is demanded, and which is examined at many points on the canal. Between the collecting offices supervision is exercised

by the agents of the administration who have to control and report all movements and all operations made.

A general control is easily exercised in the following manner:

Each collecting office sends every month to the administration an account of the bills of payment it has delivered and of those it has withdrawn. By comparing these two accounts from all the offices the certainty can be obtained that all the dues have been collected.

The traffic on these canals was in 1892, 465 489 tons, and was composed as follows:

Midi Canal, principal line	208 725 tons.
Junction Canal and Robine de Narbonne . . .	53 623 "
Garonne Lateral Canal	203 136 "

The average annual receipts during the last ten years (navigation dues only) have been in round numbers fr. 1 250 000.

The annual expenses (including general expenses) have been during the same period in round numbers fr. 1 080 000.

It should be added that on these Canals there are other sources of income, such as those arising from plantations, letting, etc. of which the annual amount during the same period was about fr. 310 000.

IV. — CANALS BELONGING TO THE CITY OF PARIS.

The canals of the city of Paris are three in number, viz.:

The St. Denis Canal,

The St. Martin Canal and

The Ourcq Canal.

They were remitted by a perpetual concession to the city of Paris by the law of the 29th Floréal of the year X, and a decree of September 4th 1807. The town again conceded them, but bought them back in 1861 and 1876. They are at the present day administered directly by the city of Paris.

The St. Denis and the St. Martin Canals form the two branches of a canal crossing a watershed and running from the Seine (St. Denis) to the Seine (below the Pont d'Austerlitz). The separating reach is formed by the basin of la Villette. Each of the two branches has retained its special denomination. Their principal object is to allow boats coming on the one side from the lower Seine and on the other from the upper Seine access to the basin of la Villette and the intermediate ports.

Their tariffs are not exactly the same and boats using the St. Denis canal are allowed to be of larger dimensions than those navigating la St. Martin canal.

The St. Denis canal from the Seine (St. Denis) to the basin of the Vilette has a length of 6 647 km.; the incline was formerly regulated by

12 locks. At the present day this canal is so altered that it has not more than 7 locks.

The St. Martin canal starting from the Seine below the Pont d'Austerlitz to the basin of la Villette has a length of 4 533 km. and the incline is regulated by 9 locks.

The Ourcq canal is an alimentary canal. Starting from la Ferté-Milon it issues in the basin of la Villette after a course of 107.9 km. It brings to this basin water for the supply of the St. Denis and the St. Martin canals, and at the same time water for the public service of the town. The total incline of this canal is 15.35 m., which is regulated by the incline of the reaches, as well as by 10 locks. It is only used by a particular class of boats, called *flûtes d'Ourcq* which are 3 metres wide and 28 metres long.

On the St. Denis and St. Martin canals the general tariffs are fixed per ton per lock. The lock taken as the basis of the lock tariff is the old lock, that is to say that, although in consequence of the alteration of the St. Denis canal two or four locks have been replaced by one, the boat pays for this one lock as much as formerly had to be paid for the two or four old locks.

On the St. Denis canal merchandise is divided into five classes.

The first class includes sugar, molasses, timber, flour, wheat, corn, fruit, metals, groceries and all merchandise not named in the other classes.

The 2nd class tiles, bricks, lime, cement, pottery and charcoal.

The 3rd class building materials and combustibles.

The 4th class straw, fodder, earth and manure.

The 5th class water.

The tariffs per class are as follows:

	Per ton per lock.
1st class	7 centimes.
2nd "	6 "
3rd "	5 "
4th "	4 "
5th "	2 "

On the St. Martin canal merchandise is likewise divided into five classes.

The 1st class includes wines, spirits, and all liquids.

The 2nd class groceries, flour, wheat, corn, fruit, combustibles, timber, wood-work, quick-lime, slates, tiles, etc.

The 3rd class fire-wood, hewn stone, sandstone, flagstones and mill-stones.

The 4th class turf, old iron, rough castings, plaster-stone and lime-stone.

The 5th class water, earth, rubbish, etc.

The tariffs per class are as follows:

	Per ton per lock.
1st Class	20 centimes.
2nd "	10 "
3rd "	7½ "
4th "	5 "
5th "	3 "

On the Ourcq canal the general tariffs are per ton per distance of five kilometres.

For the collection of the rates there are six classes of merchandise.

The first comprises charcoal and dried night-soil.

The second cement, water, dung, night-soil, sugar, molasses, liquids and generally all merchandise not named in the other classes.

The 3rd class sawdust.

The 4th class carbonised turf, hewn stone, beet-root and pulp.

The 5th class turf, turf-dust, charcoal, paving-stones, straw, hay, lucern, corn, flour, bran, offal and salt.

The 6th class coal and coke.

The prices are different accordingly as the transport is effected ascending or descending.

They are as follows:

	Per ton per distance of 5 kilometres.	
	descending.	ascending.
1st Class	10 centimes.	4 centimes.
2nd "	6 "	
3rd "	5 "	
4th "	4 "	
5th "	3 "	
6th "	2 "	2 "

Empty boats are exempt from all dues on the Ourcq canal; on the St. Denis and St. Martin canals they only pay when they have not traversed or are not about to traverse the canal with cargo, that is to say that an empty boat having discharged on one of the canals, or about to load there is allowed freedom from dues in going or returning for the same number of locks as it passed or will pass when loaded.

Empty boats are subjected to the following tariffs:

	Per lock.	
	St Denis.	St Martin.
Per boat gauging 200 tons or more	f 3.75	f 5.00
" " " 150 to 199 tons	" 3.00	" 4.00
" " " 100 " 149 "	" 2.25	" 3.00
" " " less than 100 "	" 1.50	" 2.00

On the canals of the town all boats whatever may be their tonnage and their cargo pay a supplementary due of 50 centimes for each lock or bridge passed at night.

Special tariffs are very numerous on these canals and in reckoning navigation dues they are applied more frequently than the general tariffs. It would be long and useless to quote them, so we will confine ourselves to pointing out their principles and to indicating the seven categories in which they may be arranged:

1st Category. — Special tariffs for merchandise of all kinds coming from some fixed point to any destination on the canal.

The most important of these tariffs is in force on the St. Denis canal and applies to merchandise coming from Rouen. It is a fixed rate of 50 centimes per ton, which is equal to a reduction of 25 % on the general tariff.

2nd Category. — Special tariffs for certain kinds of merchandise coming from some particular place to any point on the canal.

We would point out, as coming under this category, a special tariff on the St. Denis canal for merchandise from the Oise, and destined for any place on the canal, provided it does not consist of hewn stone, building materials, coal, wood or carbonised turf.

On the Ourcq canal special tariffs made by contract or per ton per distance of 5 kilometres for rough stones, bricks, hewn stones, tiles, lime, plaster and wood, special tariffs which are fixed according to the point of embarcation of these goods, and solely for the descent. A certain number of these tariffs, and especially those relating to rough stones, lime and plaster are zone tariffs.

3rd Category. — Special tariffs for certain kinds of merchandise going from one fixed point to another.

In this category we find:

On the St. Denis canal a special tariff of 20 centimes per ton for boats carrying sugar from Villenoy (Ourcq) and destined for the stations of Aubervilliers and Flanders. The reduction on the general tariff is 35 %.

A special tariff in exactly the same conditions is applied on the Ourcq canal.

On the St. Martin canal there is a special rate for boats loaded with bricks, tiles or slates coming from the lower Seine, and bound for la Villette. This special rate is based on the superficial area of the boat.

4th Category. — Special tariffs for certain kinds of merchandise traversing a certain minimum distance on the canal.

Under this category there is on the St. Martin canal a special tariff of fr. 1.00 for wines, spirits and other liquids passing through at least six locks. The reduction is sometimes as much as 20 % on the general tariff.

5th Category. — Special tariffs for merchandise traversing the entire canal without discharging.

These tariffs are very complicated, as they depend on the origin and destination of the merchandise.

For instance, on the St. Denis canal boats passing from the lower Seine to the upper Seine with their entire cargo pay 20 centimes per ton, that is, they enjoy a reduction which may reach as much als 75 % on the general tariff.

On the St. Martin canal boats passing from the upper Seine to the lower Seine pay as if empty.

6th Category. — Special tariffs for return cargoes when the boats have already traversed the canal loaded.

On the St. Denis canal boats coming from the lower Seine, and destined for the basin of la Villette, or for the St. Martin canal are free of all dues for return cargoes.

On the St. Martin canal the same rule applies to boats having passed at least six locks on this canal.

In addition to navigation dues proper on the Denis and St. Martin canals harbour and wharf dues are levied.

These dues are rather complicated, and we do not consider that the study of them comes within the scope of this report.

We must add that by a prefectoral decree of January 24th 1881 all navigation dues on the canals of the city of Paris were reduced by one fifth; the dues now levied are thus only four fifths of those given above.

On these canals the only collecting office is at la Villette. There is however an auxiliary office for the purpose of receiving only on the Ourcq canal. The mode of collection in practice on the st. Denis and St. Martin canals is somewhat different to that on the Ourcq canal.

On entering the St. Denis and St. Martin canals at the locks on the Seine each boat receives a pass. This pass contains all the information necessary for the application of the tariffs: the starting place of the boat, nature of the cargo, immersion of the scales, and the destination of the merchandise according to the bargeman's declaration. This document is examined at all the locks and moveable bridges passed by the boat, and the immersion of the scales and the nature of the merchandise is checked. If, however, the boat effects a partial or total loading or unloading the fact is noted on the pass by the agent of the district in which it takes place, together with the name of the place and the dates of the commencement and finishing of the operation. When a boat has discharged or taken in its cargo and is ready to leave the canals, it has to make application at the collecting office at la Villette, and state by which route it is desired to depart. It has to produce at the same time its bill of lading, its pass and its certificate. The account of the dues is inmediately made out, the bargeman pays the account, and obtains a receipt for it. The pass is then stamped to show that it has been seen, and permission given to depart up to a certain date and by way of a certain canal. Provided with this document he can leave the canal; it is, however examined, under the same conditions as on arrival at the departure locks, and if the exit is not effected according to the conditions noted on the pass, supplementary dues are charged, which have to be paid before the boat definitely quits the canal.

The passes are delivered up at the last locks, and sent back by the collecting office at la Villette, where they are again controlled.

On the Ourcq canal the mode of collection is nearly the same, the same pass is used, the same details and the same indications are noted on it, the only differences being the following:

The passes are delivered on the ascending journey, and serve for this as well as for the descending journey.

The pass is always withdrawn as soon as the descent is completed. If the boat descends as far as the inside of the fortifications of Paris the system applied is absolutely the same as described above.

In the contrary case the pass is withdrawn and is sent by the district agents to the collecting office at la Villette, which makes out the account and requests payment from the owner to be made either at that office or at the auxiliary office on the Ourcq canal. This system is possible, because the boats in question do not leave the waters of the Ourcq and consequently cannot escape payment of the dues.

It will be seen that the control on the route is assured by the examination made at the locks and moveable bridges, as also by the obligation of presenting the pass at any point, whenever it is demanded by an agent.

A general control is exercised by the return of the pass to the collecting office as soon as the boat has left the canal or completed its journey, as well as by the keeping at the locks of a record of the passages made, and on the Ourcq canal of a record of the unloadings and loadings effected each week in the different parts of the canal. By comparison made between these records and the passes assurance is obtained that no dues have escaped collection.

The general tonnage on the canals of the town in the year 1892 was 3 509 358 tons, composed as follows:

Ourcq Canal	743 922 tons.
St. Denis „	1 686 629 „
St. Martin „	1 078 807 „

The average annual receipts calculated on the last ten years amount to:

For navigation dues proper in round figures 817 000 francs distributed as follows:

Ourcq Canal	126 000 francs.
St. Denis „	430 000 „
St. Martin „	261 000 „

To this must be added various other profits which during the same period have amounted annually to about 265 000 francs, thus bringing the total receipts up to 1 082 000 francs.

The annnal cost of maintainance, not including general expenses, amounted to 440 000 francs.

During this last period of ten years the amount expended by the city of Paris for repairs and improvements on the St. Denis canal and on the basin of la Villette was about sixteen millions of francs.

V. — CANAL FROM THE SAMBRE TO THE OISE.

The junction canal between the Sambre and the Oise begins at Landrecies and terminates at La Fère. It unites the basin of the Meuse with that of the Seine. Its length is 71 kilometres and it is divided into reaches. It has 38 locks of which 3 are on the side of the Sambre and 35 on that of the Oise.

It is handed over to and administered by a private company.

The general tariffs are per ton per distance of five kilometres.

Merchandise is divided into six classes and we are about to show the principal constituents of each of them:

1st class. — Charcoal, petroleum and all objects not named in the other classes.

2nd class. — Corn, flour, hay, fruit, pit-coal, sugar, molasses, etc.

3rd class. — Lime, cement, hewn stones and flagstones, wood of all kinds, lead, zinc etc.

4th class. — Bricks, rough stones, iron bars, rails etc.

5th class. — Coke, chalk, coal-cinders, sulphates etc.

6th class. — Tar and pitch, old iron, old castings, plaster, manure, earth etc.

The tariffs are the same for both directions and are as follows:

	PER TON PER DISTANCE OF 5 KILOMETRES.
1st class	20 centimes.
2nd "	15 "
3rd "	10 "
4th "	8 "
5th "	6 "
6th "	5 "

Empty boats whatever may be their size pay a fixed due of 2 francs per distance of 5 kilometres.

No supplementary dues are levied for navigation at night.

Special tariffs only exist for wood-floats, for which every tree of an average circumference of one metre or more pays 20 centimes per distance of five kilometres, while those of a lesser circumference pay 10 centimes.

Floats of fire-wood pay 10 centimes per metre in length.

We may add that the Company agrees in certain cases on the authority of the Administrative Council to reductions on the general tariffs, and further, takes upon itself the gratuitous towage of empty or loaded boats in accordance with the above rates.

There are also on this canal, as on the St. Denis and St. Martin canals, harbour dues.

The collection of the navigation dues is effected by four offices, established one at each end of the canal, and two others in the course of the route.

Payment of the dues is made in advance and alterations made in the course of the journey are regulated by supplementary payments or allowances.

When a boat enters the canal the boatman makes his declaration at the receiving office. The collector gauges the boat, makes out an account of the dues, and receives the amount of the same; hands to the boatman a receipted pass, together with a control ticket.

These documents contain all particulars required for the control on the route, such as place of starting, destination, nature of cargo and immersion of scales.

If the boat traverses the entire length it delivers up to the receiving office when leaving the canal the control ticket, keeping the pass, which serves as a receipt.

If, on the contrary, the destination is within the limits of the canal he delivers up the control ticket to the nearest agent before any loading or unloading is effected.

If a boat commences its journey within the limits of the canal, it must in the first place be provided with a similar pass. For this purpose the tonnage and nature of the cargo are controlled by the nearest agent, and he reports the particulars to the nearest receiving office. When the boatman reaches this office he receives his pass with the particulars noted on it.

Control on the route is administered by the lock and bridge keepers examining and certifying the pass, and by all the agents of the canal who may demand its production at any point of the way. At the passing of the boat each of these agents has to compare the nature of the merchandise and the draft with the indications given on the pass. The agent who receives in the last instance the control ticket compares the indications given on the pass with the cargo. The locks are very close together and the interior traffic somewhat limited, the control is therefore comparatively easy.

General control is effected by verifying the entries and the calculations of the receivers and comparing the sums collected with the control tickets handed in by the bargeman.

In 1892 the tonnage on this Canal amounted to 849 751 tons.

The average of the annual receipts for navigation dues proper during the last ten years was in round numbers	843 000 francs
For other profits (letting, trees, grass etc.)	26 000 "
Total . . .	869 000 francs.

The cost of maintainance and administration including general expenses averaged during the same period 482 000 francs.

VI. — CANAL FROM ST. DIZIER TO VASSY.

The canal from St. Dizier to Vassy is a branch of the Haute Marne canal and its length is 23 kilometres. It begins at Brousseval, and extends to Hoëricourt, where it joins the principal line. Its incline is regulated by 8 locks. It was conceded to M. Festugièr, who by a later decree handed it over to „La société des Forges de Champagne".

The general tariffs are per ton per kilometre and merchandise is divided into four classes, viz.

1st class. — Iron ore, stone and sand.
2nd „ — Pit-coal and coke.
3rd „ — Wood, cast-iron and rough iron.
4th „ — Merchandise not mentioned above.

The tariffs are the same for ascending or descending and are to follows:

	Per ton per kilometre.
1st Class	3½ centimes.
2nd „	4 „
3rd „	5 „
4th „	6 „

Empty boats whether ascending or descending and whatever be their gauge pay 50 centimes per kilometre.

No supplementary dues are charged for navigation at night, which as a matter of fact never occurs.

There are no special tariffs.

Collection is effected in a very simple manner, as there is no interior traffic on the canal. There is only one collecting office which is situated in the lock at the junction with the Haute Marne Canal.

When an ascending boat enters the canal the bargeman makes his declaration and produces his bill of lading to the collecting lock-keeper, who makes out an account of the dues, receives the amount, and taking a receipt from a register, delivers it to the bargeman to whom it serves as a pass.

This pass has to be shown whenever it is required by any agent, and to the lock-keepers who enter in a register kept for the purpose the passage of the boat, its starting place, destination and tonnage.

On the descent the first lock-keeper below the point of departure delivers to the bargeman a ticket, whereon is stated the place of origin, the destination and the tonnage. This ticket is controlled on the descent by every lock-keeper on the route; he marks on it the hour at which his lock was passed and enters the fact in a register.

On leaving the canal this ticket is delivered up to the collecting lock-keeper, who collects and gives a receipt for the dues. In certain cases this ticket may serve to rectify the account of the dues collected on the ascent, when the place of destination is not the same as was indicated at

the time of ascending. The control on the route is effected by the lock-keepers at the passing of the boat, and is further assured by an inspector, and the Director of the Administration, who on their periodical visits easily see that no boat has been omitted, that the destinations and starting places have been properly noted and the dues regularly paid.

The general control is effected by comparing the account of receipts of the collecting lock-keeper with extracts from the passage books kept by the other lock-keepers.

The administration of this canal is most simple, and in accordance with the insignifiance of and the lack of variation in the tonnage.

In 1892 the tonnage amounted to 182 676 tons.

The average annual receipts for navigation dues proper during the last ten years were	107 000 francs.
for divers other receipts	9 000 "
Total	116 000 francs.

The average of the annual expenses during the same period including general expenses was 24 000 francs.

VII. SUMMARY AND CONCLUSIONS.

From the above study of the system of tolls levied on navigable ways in France the following general conclusions appear to arise.

On nearly all the navigable ways the general tariffs are calculated per ton and according to the distance traversed. The unit of distance is generally the kilometre, although on some canals it is five kilometres. On the St. Denis and the St. Martin canals, which are of short length and have many locks, the general tariffs are, however, fixed per ton per lock.

Merchandise is divided into a certain number of classes and most freguently in accordance with its value. The number of classes varies on the different ways from 2 to 6.

The rate of tolls varies according to the navigable way, and to the class in which the merchandise is comprised. It is generally lower in proportion as the merchandise is less valuable. On ways where the tarift is fixed per ton per kilometre the toll varies from 2 to 6 centimes, on those where it is fixed per ton per distance of 5 kilometres it has a minimum of 2 and a maximum of 30 centimes; and on those where the toll is levied per ton per lock the rate varies from 2 to 20 centimes.

On the principal navigable ways still subject to toll there are in addition to the general tariffs, special tariffs applicable to certain kinds of merchandise of a fixed origin or destination. On these ways these special tariffs are of more frequent application than the general tariffs, and allow of reductions varying from 15 to 80 $^0/_0$ on the general tariffs.

They appear in the form of special reduced tariffs per ton per

distance traversed, also in the form of a special rate for a certain distance or for the entire traverse of the canal, and again in the form of a tariff per zone.

Empty boats are either exempt from toll (in a general way or under particular conditions) or are allowed reduced rates.

No special dues are collected for the manoeuvring of locks, weirs or bridges.

It is only for the passage of locks and moveable bridges at night on the Midi Canal and the canals belonging to the city of Paris that special dues are charged, which are fixed and independent of the tonnage of the boats.

The collection of dues is facilitated by the system of gauging applied to every boat travelling on the navigable ways in France, the certificate with which it has to be provided and the scales on the hull.

The calculation and the collection of the dues are effected in a certain number of offices, generally established at each extremity of the way, and at the principal points on the route; the work is aided by the co-operation of all the agents of the maintenance and the administration on the canal.

Every boat travelling on a navigable way, on which tolls are levied is supplied with a document without which it is not allowed to travel. This document, which constitutes a pass for the boat, may be compiled in various forms. If the dues are paid in advance it is a receipt pass; if the dues are not collected until the course is effected, it is a bill of lading which on certain ways indicates the amounts which the bargeman will have to pay.

This pass is for a single journey and takes effect as soon as the boat enters the canal, or commences a journey upon it. It is delivered by the agent of the district in which the boat is, or at the first collecting office on the route. In this latter case the boat is supplied by the first agent with a provisional document, which takes the place of the pass until the nearest collecting office is reached.

This pass contains all information necessary for the collection of the dues, such as the origin and destination, nature of merchandise and immersion of scales.

Any alteration of the particulars indicated is noted by the agent of the district, in wich the alteration takes place, and the resulting change in the calculation of the dues to be paid is made at the nearest collecting office. If the dues have been paid in advance the difference is here collected or returned; if the pass indicates the sum due a modification is made in the account; and if the account is to be made at the end of the journey the alteration is simply noted on the pass.

When a boat leaves the canal or reaches its destination it delivers up its pass to the nearest agent.

When the pass is receipted, the receipt is held by the bargeman, but a part of the pass has to be given up.

The obligation laid on the bargeman of having this document always with him allows of control on the route. The pass is examined und stamped at every receiving office and at every lock and moveable bridge passed. The agents charged with this duty note in the pass the time of passing, and the depth as shown by the scales.

This document must be produced on the demand of any agent in the course of the route.

No boat can load on the canal and commence a journey without being provided with this document, nor can it discharge cargo without first delivering up this document to the agent of the district in which the operation takes place. The agent has then to satisfy himself that the boat is in the condition indicated in the pass. No partial loading or unloading is permitted until the agent of the district in which the operation takes places has properly modified the pass, or forwarded a report of the alteration to the nearest receiving office in order that the modification may be made there.

The general control is effected by the verification of the accounts in the receiving offices; as well by comparing the sums received and the receipts delivered at the offices with the passes, or portions of passes delivered up by the bargemen to the agents, and which have been returned to the same office, or to the central office.

(Translated by G. J. ROWLAND.)

19

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.

THE HAGUE, 1894.

5th QUESTION.

TOLLS ON NAVIGABLE WAYS.

BY

A. DEKING DURA,
Chief Engineer of the Provincial Waterstaat at Zwolle (Overijssel).

THE HAGUE,
Printed by Belinfante Bths, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

VIth International Inland Navigation Congress.

THE HAGUE, 1894.

TOLLS ON NAVIGABLE WAYS.

BY

A. DEKING DURA,

Chief Engineer of the Provincial Waterstaat at Zwolle (Overyssel).

INTRODUCTION.

On account of the difficulty and the complication of the subject, it is almost impossible in this report to treat in its entirety the question of Tolls on Navigable Ways; we will therefore confine ourselves to searching out the rational basis of a tariff of tolls on a system of canals of large extent, administered by the owners (State, Province, Commune, Syndicate or concessionary company) who do not undertake themselves the working of the traffic, but merely the construction and maintainance of the waterway and of the working of bridges, locks, tolls etc.

We will leave on one side also the subject of harbour and quay dues, as well as that of tolls paid for the use of plant for loading, unloading, towage etc. and consider solely the question of navigation dues in its proper sense and of tolls for the working of bridges and locks.

Tariffs of tolls.

The six reports on tolls presented at the Paris Congress contain important information concerning rates of navigation dues in use in the authors' own countries, namely, France, England, Germany, Russia and the Netherlands. With regard to Belgium very complete information is given in the „Règlement de Police sur les Voies Navigables" as it appears in the „Moniteur Belge" of May 29th 1889, N^{o}. 149.

Particulars are likewise furnished respecting navigation dues on the German canals, those completed as well as those in course of construction and those projected, in the communications of the „Central Verein für Hebung der deutschen Fluss- und Kanalschiffahrt." Lastly a report to the Administration of the Danube Steamship Company by the Vienna

engineer J. DEUTSCH, a delegate to the Paris Congress, contains information as to the tariffs in force on the Danube and on the Franzens Canal in Hungary.

In order to compare these tariffs, it is necessary to calculate the tolls paid at the kilometric ton rate (except in cases where this rate already forms the basis of the tariff) and this calculation is not without some difficulty. If an approximate calculation may be made with comparative ease for the tariffs of the Netherlands, where the tolls are mostly reckoned by cubic metre per lock, it is not practicable to do this with the Russian and Austro-Hungarian rates.

In Russia the rates are calculated at a percentage on the value of the merchandise carried, without any reference to the length of the waterway traversed. On the Danube the dues have rather a fiscal character, being calculated at a percentage on the gross freight receipts. Finally on the Franzens Canal the rates are fixed in proportion to the tonnage of the vessel and the duration of the voyage.

The tariff shown in annex A, which is composed with the help of the reports above mentioned, gives a view of the dues in France, Belgium, England, Germany and the Netherlands.

An examination of this table shows:

1°. That the dues on the English canals are generally higher than in other countries.

2°. That the dues on canals of concessionary companies are higher than those belonging to the State or to other public bodies.

This is particularly the case with canals belonging to railway companies.

3°. That in a great number of cases the rates are proportionately higher on canals of short length.

4°. That on waterways not belonging to concessionary companies the dues vary:

In Belgium, on canals from 0.2 to 0.5 centime.
" " on canalised rivers from 0.16 to 0.5 centime
the rule being 0.5 centime on Canals and 0.16 centime on canalised rivers.
In the Netherlands from 0.24 to 0.65 centime on the canals.
In Germany (with the exception of the Ludwig Canal) from 0.15 to 1.25 centime.

It can be easily understood that it is impossible to fix a tariff of dues which should not in any case be exceeded.

The example of the canals of Paris shows that especially on canals of short length, situated near large centres of population, a very high toll may be applied and still permit of a large development of navigation.

It must be borne in mind, that canals used for transport at long distances have to suffer the competition of railways and that if the economical object of their construction is to be attained, it must be possible to transport goods and especially raw material and cheap merchandise cheaper than by rail. Now as the rate for such freight by rail is about

3 centimes per kilometric ton (see Sympher „Wirtschaftliche Bedeutung der Binnenwasserstrassen"), we must come to the conclusion that a toll of 1.2 centime does not leave margin sufficient for the transport by canal to be the cheaper and that to attain the economical object of the construction of the canals, it will be necessary to lower the rate by one half, that is to about 0.6 centime.

Still even this low rate would hinder the developpement of navigation and render it impossible to transport by water to long distances, especially on canals of insufficient dimensions and those inadequately provided with plant.

Influence of the distance traversed, of the tonnage of the vessel and of the nature and quantity of the goods carried. Classification of merchandise. Exemption from or reduction of toll for vessels travelling without cargo.

In calculating navigation dues the above-mentioned points are variously regarded in different countries.

To arrive at a just appreciation, it would be well to examine one after the other what we may call the Franco-Belgian, Dutch and German systems.

In Belgium the navigation dues are fixed by tons of 1000 kilogrammes per kilometre traversed, with a minimum of 20 centimes. They are charged on the distance actually traversed and on the quantity of merchandise carried. Empty vessels pay a toll of 20 centimes whatever may be their tonnage and independant of the distance traversed.

All merchandise, whatever may be its nature or value, pays the same dues. But for the advancement of agriculture, vessels carrying manure are exempted from all dues, even from the 20 centimes, when travelling empty.

Vessels employed in a regular service, pay a reduced rate, which is based on the total of the cargo they are able to carry. The reduction is three-quarters for regular passenger services, five-eighths for mixed services and one-fourth for cargo services.

In Holland the duties are not in proportion to the quantity of merchandise carried, but to the tonnage of the vessel.

The distance traversed is only indirectly taken into consideration. Toll offices are placed along the sides of the canals and a fixed rate per ton is charged at the passing of each office.

Vessels travelling without cargo are sometimes entirely exempted from toll, but more often they pay the half of the usual tariff.

The same reduction is often allowed to vessels running a regular service and to such as carry only manure. On the other hand we sometimes find, as for example in Friesland, that steamers have to pay an increased tariff to the amount of 50 or 100 % on account of the damage they cause to the banks of the canals.

In general the nature of the merchandise carried is not taken into con-

sideration and there is no classification. There are however some exceptions expecially in the tariffs of the canals in the turf districts.

The German system holds a middle place between the Franco-Belgian and the Dutch. The dues are in proportion to the tonnage of the vessel and to the distance traversed, with, however, a modification of a rather fiscal character.

Every fraction of five tons or of five cubic metres is reckoned as five tons and any fraction of a kilometre transversed is likewise counted as a kilometre. This method of calculation presses rather heavily on some vessels, especially on small ones and those which travel only short distances.

Up to the year 1892 vessels of a large tonnage enjoyed an exceptional privilege on the canals between the Elbe and the Oder („Märkische" canals). This was caused by the fixing of a maximum toll, corresponding to a tonnage of 155 tons. The average tonnage of the vessels on these canals is 400 cubic metres. The toll per kilometric-ton was by this means reduced by more than one half, whereas on the smaller vessels it was charged in full.

Unloaded vessels on the Finow Canal pay one-sixth, those on the canals of the left bank of the river Ems two-fifths of the ordinary toll. They are thus more favoured than in Holland, but still far less so than in Belgium.

Account is also taken of the nature and value of the goods carried.

On the canals between the Elbe and the Oder raw material pays only one half of the ordinary tariff, whereas on the left bank of the Ems boats so laden are treated as empty vessels. The latter however pay higher dues on the left bank of the Ems than on the „Märkische" canals.

When the above-mentioned privileges in favour of vessels of large tonnage on the „Märkische" Canals were abolished, the general rates were at the same time increased by a third.

The justice of this abolition has been generally recognised, but at the same time it was demanded, that the reform should be completed by the dues being calculated on the actual quantity of merchandise carried, especially as it often happens that vessels can only partly utilise their carrying capacity, on account of the shallowness of the water in parts of the rivers they traverse.

The raising of the tariff has been protested against and the adoption of the Franco-Belgian system demanded. Until now however these demands have not been complied with. The Minister of Finance has objected, that the dimensions of the canal depend on those of the vessels and that therefore one may doubt the superiority of the principle of proportioning the toll to the quantity of merchandise carried to the one based on the tonnage of the vessel. He also doubts the practicability of this last method of calculation, a doubt which appears to require foundation after the experience gained in Belgium.

Before discussing the consequences to be deduced from the above-

mentioned facts, it is right to remark, that the Dutch system, although it is to be recommended for its simplicity and is well adapted to the particular conditions of the country, could not be applied to a system of canals of great extent. In fact the country on account of its limited size possesses only short canals connecting natural rivers, or rivers with an inland lake, so that the navigation is of a mixed character.

It is the Franco-Belgian and the German systems which must furnish the basis of a rational tariff applicable to such a system.

In considering the question of the influence of the tonnage of vessels and of the quantity of merchandise carried, we remark that those who assert that the price of construction and maintainance of the canal depends on the dimensions of the vessels, as well as those who maintain that it is unjust to make the boatman pay for that part of the capacity of his vessel which, entirely independent of his own will, he is unable to use, are both right.

Thence arises the question, whether it is not possible to combine the two principles. We believe that this could be arrived at by reducing the toll into a fixed tariff, independant of the distance and proportionate to the tonnage of the vessel, the tariff to be applied to all vessels, loaded or unloaded and a toll proportionate to the number of tons carried, varying with the distance of the transport.

It must be acknowledged that empty vessels do profit by the canal and that it is only just that they should pay a toll. At the same time it is certain that a large vessel profits more than a small one and this iustifies the proportioning of the tonnage. Still it cannot be denied that a long journey without cargo is a disadvantage to the vessel, so that it is unreasonable to tax it in proportion to the length of this unprofitable journey. Empty vessels might therefore be charged a moderate fixed toll — say 10 centimes per ton.

Then by obliging loaded vessels to pay this same toll, we obtain the result that a large vessel, which uses the dimensions of the canal much more completety and which in general will be the cause of much greater expense for maintainance of the same, will pay more than a smaller vessel carrying the same quantity of merchandise. In this way the principle enunciated by the Minister Miquel in the discussion on the tariffs of the „Märkische" canals will be complied with.

Having in this manner allowed all due influence to the tonnage of the vessel, it is inevitable that the toll to be paid for the transport of the merchandise should be proportionate to its quantity, viz., the number of tons transported. The example of Belgium shows that the practical inconvenience found in this method of charging dues is not insurmountable.

For this reason the system of gauging vessels used in Belgium should be adopted and a concession made for vessels doing a regular service.

For these the application of this principle would meet with many difficulties on account of the perpetual variation in the quantity transported, especially when the object of the service is exclusively the transport of passengers.

But this difficulty is obviated in a very judicous manner by the Belgian rules which charge on these vessels a reduced toll but which is still calculated in proportion to the tonnage.

We have now to examine the following questions:

1. *Is a classification of merchandise desirable?*
2. *Should the toll be in proportion to the distance traversed, or is it preferable to form a tariff in which the kilometric charge decreases with the number of kilometres traversed?*

The solution of the first question is simple. The freight of raw material is lower than that of merchandise of less volume and greater value. The latter can thus in general bear heavier charges and the toll should therefore be higher than that for the raw material. Still, if the classification be pushed too far, many difficulties would arise in the calculation of the toll especially for mixed cargo. Instead of determining the quantity transported by means of gauging, a declaration concerning the nature and quantity of each article should be required from the boatman. In this respect it would be advisable to adopt the German system, which distinguishes only two classes of merchandise, viz. raw material and other merchandise, the toll due on the latter being the higher.

Of course it will be necessary to decide in each particular case, what merchandise is raw material and what is to be the difference of the toll for the two classes. In certain cases the classification might present such important difficulties, that it would be better not to apply it.

The solution of the second question is less simple, but it is in our opinion of the greatest importance.

Although until now, in Germany as well as in Belgium, the principle of proportion to the distance traversed has been adhered to and in fact the supposition has been generally allowed, that the damage caused by a vessel becomes greater in proportions to the distance traversed, the practical as well as theoretical objections that can be made to this principle seem of so serious a nature that its maintainance is not to be recommended.

To begin with, the expenses of maintainance are composed of a great number of elements among which are some that do not depend in any way on the number of kilometres traversed by the vessels.

Also, the freight is not proportionate to the distance. In general the kilometric freight decreases with the distance traversed. Many cases may be quoted, in which one and the same freight is charged for the transport of the same quantity of merchandise to very different distances.

It follows that the consequence of the application of the principle of

kilometric proportion is that with the increase of the distance a gradually increasing proportionate part of the freight is absorbed by the toll, and a limit is soon reached, whereat this proportion is such that the transport of the merchandise cannot be effected with any advantage.

Proof is abundant that the influence of the truth has not been without its effect in the compilation of existing tariffs.

For instance in Russia with its enormous distances, it was immediately perceived that the introduction of the principle of the proportion of tolls to the distance traversed would lead to the formation of tariffs so burdensome that all transport by waterway would become impossible and the system of charging dues according to the value of the merchandise has been adopted, a system which has moreover little to recommend it. It has been already observed that the tolls on canals of short length are generally the highest.

In a recently published pamphlet concerning the canal from the Rhine to the Weser and the Elbe, the engineer Geck estimates that the average of the toll per ton transported will be mk. 0.84 and he remarks „that the introduction of this average toll would be a great advantage to the transport over long distances, although it would bear too hard upon the local traffic". That is also our opionion. For this canal, as well as for any canal system of great extent, it would be better to adopt a medium rate, establishing on a kilometric basis a tariff decreasing in proportion to the distance traversed.

It is well understood that the taxing of the tolls, the degree of the decrease as well as the classification of merchandise and the proportionate tax on the tonnage of vessels should in each particular case be the object of a special enquiry and it is merely in order to present clearly our ideas that we give on annex B an example of a tariff, formed on the principles we have enunciated and of its application to a canal of 600 kilometres in length used by vessels of 400 tons burden.

By this table it will be seen that the toll per kilometric ton for short distances is higher than the fundamental tax. That this tax corresponds to a transport on a distance of 170 kilometres, while the kilometric toll decreases very perceptibly with the increase of the distance.

The principle of proportion to distance traversed would lead up to a toll total of 1200 francs for raw material and of 1800 francs for other merchandise. The proposed decrease should be more or less according to circumstances depending on the nature of the transport, the total length of the canal and the development of the country. It should be the most on canals constructed for drainage purposes.

In some cases it will be advisable to suppress entirely the supplementary toll, when the distance traversed exceeds a certain limit.

Dues for working locks, weirs and bridges. Supplementary dues at night.

It may be taken as a general principle, that dues for working mechanical appliances should be included in the toll paid for the use of the canal. Considerations of a practical nature may, however, justify the creatain of separate tolls of this nature.

Dues for the working of locks are charged only in very exceptional cases.

The only instance with which we are acquainted is found in the tariff of the canals on the left bank of the Ems, where each vessel pays 20 pf. for the working of a single lock and 30 pf. for a double lock.

For the working of movable bridges it is the custom in the Netherlands to charge a small fee, which does not exceed 5 cents (one penny) for vessels of a tonnage of 50 cubic metres and is more often only $2^1/_2$ or 2 cents in Dutch currency. In such cases the man placed in charge of the bridge does not as a rule receive any regular wages, but he is allowed to occupy rent-free a small house near the bridge and to keep for his own use the money he collects in tolls.

In many instances he agrees to pay a certain rent for the use of the house together with the privilege of collecting and keeping the toll-money. His rent sometimes amounts to more than 100 florins (200 francs) a year on much frequented canals.

In places where bridges are not numerous and where the toll does not exceed the tariff quoted the inconvenience caused to navigation is not great and the system affords considerable advantage to the proprietors of the canal.

The inconvenience is lessened by a custom which the Dutch boatmen have of giving one or two cents to the worker of the bridge, even when no toll is exacted or due.

These practical considerations do not apply to locks, which must always be worked by paid attendants; neither are they applicable to bridges built after the construction of the canal which do not benefit navigation in any way. When bridges are numerous and the rate of the tolls too high, this may become such a tax on navigation as to sensibly augment the usual expenses.

For instance on the left bank of the Ems, the charge is 10 pf. per vessel per bridge, and one finds on the average a moveable bridge at every kilometre. For vessels of 60 to 80 tons traversing these canals the charges amount to a tax of 16 to $12^1/_2$ pf. per kilometric-ton, whereas the toll in itself is most often not more than 2 pf.; for smaller vessels the tax is still more onerous.

The charging of dues for the working of weirs may be justified by the consideration that it is often a matter of importance that the frequency of these manoeuvres be diminished as much as possible.

In such cases a rather high toll is fixed for each time the gates are worked, so that the boatmen find it to their own interest not to require this to be done, until there are several vessels wanting to pass through collected together and then each one pays a share of the toll, thus dividing the burden.

With regard to supplementary dues at night two cases must be distinguished.

When the traffic is not animated and navigation at night only carried on in exceptional cases, a moderate toll is justifiable and practical even if it be only applied with the object of inducing the boatmen to refrain from travelling during the night, except in cases of great necessity. In this case it is only just that the profit of this night work should go to the benefit of the lock and bridge workers.

When however the traffic is of sufficient importance to justify the introduction of a regular night service, it is advisable to encourage navigation at night with the object of obtaining traffic as busy as during the day. In this case all motive for the application of an extra tax at night disappears.

Mode of collecting. Control.

The mode of collecting must comply with the following conditions:

1. It must cause as little delay as possible to the vessel.
2. It must render it impossible, or at least extremely difficult, for any fraudulent connivance to take place between boatmen and collectors and thus prevent any misappropriation by the latter.
3. It must permit of the formation of good statistics of navigation.

A system which in practice on the canals of the province of Overijssel has given satisfactory results, is based on the following principles, which may be modified or applied in a different manner accordingly as circumstances may differ.

Every boatman on entering the canal, or on changing the direction of his vessel after loading or unloading a cargo, receives at the first office he comes to a ticket, which is detached from a book of numbered leaves. On the part left in the book, as well as on the ticket, are entered the name and the maximum tonnage of the vessel, the name of the person in charge of her, also if the vessel is loaded the depth of water she draws, as indicated by the gauge, and the nature of the cargo with its classification.

The boatman is obliged to show his ticket at every office he passes and it is examined by a clerk, who signs it or clips it in a particular part in the same way as is done with railway tickets, and registers the passage of the vessels in a book kept for the purpose. If the gauge indicates that the cargo has been increased or diminished he notes the fact on the ticket.

After having passed one or more offices the vessel may either pass out of the canal or discharge its cargo and continue the journey or turn back.

In either case the boatman delivers up his ticket at the office of the canal or at the first office he reaches. The clerk makes on the ticket itself a calculation of the amount of the tolls due, which have to be paid before the journey can be resumed.

If the vessel has not left the canal a fresh ticket is issued.

The tickets with the amount of the dues paid noted on them together with the corresponding numbered leaves of the clerk's book are sent in at the end of each month to the general manager or superintendent, who checks them and compiles statistics from the tickets, which of course show a complete itinerary of the journey of the vessel.

The system causes very little delay to the boats, especially when the controlling offices are situated at the locks, bridges, or any of the usual places of loading.

It renders it extremely difficult for any misappropriation or fraud to be committed by collectors on boatmen, for it could not possibly take place without collusion between several persons, and because all tickets have to be sent in within a certain time, and the books show at any time on what section of the canal and between which two offices any vessel may be found. It would thus be easy to discover any fraud committed by a collector.

The control is facilitated by the tickets being of two different colours, one for each of the two directions. It is also found necessary to inflict a heavy fine on any boatman who cannot or will not show his ticket whenever it is demanded by any authorised person.

For the system to work well every vessel must be gauged and supplied with certificates and a proper water-gauge.

The calculation of the dues is not difficult, when tables similar to those in use in Belgium are employed. They render it easy to trace the distances traversed and a table can be made out with double entries, from which may be extracted at first sight the amount due by a vessel which has transported a certain quantity of merchandise to any number of kilometres of distance.

The author of this memorandum holds at the disposal of members of the Congress, who take an interest in the subject, a number of specimens of the documents used by this system on one the canals in the Province of Overyssel.

Briefly, we recommend the Congress to adopt the following conclusions:

1°. *It is impossible to fix a maximum tax per kilometric ton, which could not be exceeded.*

However, a toll of 0.5 *centime or pfenning per kilometric ton may*

be considered as not to be exceeded without inconvenience on canals intended to facilitate the transport of raw material to long distances and which have to suffer competition from railways.

2°. *It is advisable to divide the toll into a moderate tax proportionate to the tonnage of the vessel and independent of the distance traversed, to be paid per journey by vessels loaded or unloaded, and a tax on a kilometric basis decreasing with the distance in proportion to the quantity of merchandise transported to be charged in accordance with a classification of the merchandise.*

As a rule it is not advisable to distinguish more than two classes of merchandise: a. *raw material,* b. *all other merchandise.*

3°. *As a matter of principle, charges for the working of locks, weirs and bridges and extra tolls for navigation at night are not to be recommended.*

Nevertheless considerations of a practical nature may in certain cases justify the establishment of such tolls on condition that they do not exceed a very moderate rate, so that the total of the dues paid be not sensibly increased.

Zwolle, March 31st 1894.

(Translated by G. J. ROWLAND.)

NAME OF CANAL.	Length of canal in kilometres.	Rate of tolls per kilometric ton. In centimes.	In pfennings.	REMARKS.
France.				
Navigable Rivers		0.15 to 0.35	0.12 to 0.28	Before the abolition of tolls in 1880.
Canal du Centre	110	0.05 „ 0.18	0.04 „ 0.15	„ „ „ „ „ „ „
„ du Midi	279	3.6 „ 3.8	2.8 „ 3.0	Canal worked by a railway company.
„ de la Dive et du Thouet . .	40	2.5 „10.0	2.0 „ 8.0	„ belonging to a concessionary company.
„ latéral à la Garonne . . .	213	2.0 „ 4.0	1.6 „ 3.2	„ „ „ „ „ „
„ de Vassy à St. Dizier . . .	23	3.5 „ 6.0	2.8 „ 4.8	„ „ „ „ „ „
„ de l'Ourcq	108	0.2 „ 2.0	0.16 „ 1.6	„ „ „ the city of Paris.
„ de St. Denis	6.6	5.8 „10.2	4.6 „ 8.1	„ „ „ „ „ „ „
„ St. Martin	4.5	4.4 „ 8.8	3.6 „ 7.1	„ „ „ „ „ „ „
State Canals		0.25	0.20	Tax proposed in 1887.
Belgium.				
Canal du Centre	7.6	0.5	0.4	Canal owned by the State.
„ from Mons to Condé . . .	20.2	0.5	0.4	„ „ „ „ „
„ „ Pommeroeul to Antoing	25.2	0.5	0.4	„ „ „ „ „
„ „ Charleroi to Brussels and branches	105.0	0.5	0.4	„ „ „ „ „
„ „ Ghent to Ostend via Bruges	70.1	0.2	0.16	„ „ „ „ „
„ „ Plasschendaele to Nieuport	21.0	0.5	0.4	„ „ „ „ „
„ „ Ghent to Terneuzen. .	17.0	0.5	0.4	„ „ „ „ „
„ „ Liège to Antwerp and branches	249	0.5	0.4	„ „ „ „ „
„ „ Rouler to the Lys. . .	16.5	0.25	0.20	„ „ „ „ „
Canals of the basin of the Yser . .	90.0	0.5	0.4	„ „ „ „ „
The canalised Lys	112.5	0.16	0.13	River canalised by the State.
The „ Meuse	128	0.16	0.13	„ „ „ „ „
The „ Sambre.	94	0.16	0.13	„ „ „ „ „
The „ Ourthe.	106.5	0.5	0.4	„ „ „ „ „
Canal from Blaton to Ath	21.5	4.0	3.2	Canal belonging to a concessionary company.
„ „ Bossuyt to Courtrai . .	15.4	3.0	2.4	„ „ „ „ „ „
The canalised Dendre	67.4	1.0	0.8	River canalised by „ „ „
England.				
Junction Canal from Liverpool to Birmingham	62	9.4	7.4	Canal belonging to a railway company.
Trent-Mersey Canal	95	3.1 to 6.1	2.5 to 5.0	„ „ „ „ „ „
Kennet Avon Canal	138	3.1 „12.4	2.5 „10.0	„ „ „ „ „ „
Canal from Bolton to Bury . . .	25	2.4 „ 3.3	2.0 „ 2.6	„ „ „ „ „ „
„ „ Birmingham to the Severn	153	4.0 „ 6.1	3.2 „ 4.9	„ belonging to a concessionary company.
„ „ „ to Warwick etc.	250	3.1 „ 6.1	2.5 „ 5.0	„ „ „ „ „ „
				NB. The figures relating to the English Canals are taken from the report of Mr. CLEMENTS to the Paris Congress. The distinction between the Companies which work the traffic themselves, and those which confine themselves to the maintainance of the Canal is not quite clear.
Netherlands.				
Overijssel Canal	56	0.92 „ 1.0	0.74 „ 0.80	Canal belonging to a concessionary company.
Dedemsvaart	48	0.27 „ 0.65	0.22 „ 0.53	„ „ „ the Province.
Zuid-Willemsvaart	78	0.32	0.26	State canal
Drentsche Hoofdvaart	44	0.24	0.20	„ „
Apeldoorn Canal	55	0.47	0.38	„ „
Germany.				
Finow Canal	70	0.28 to 0.15	0.23 to 0.12	State canal.
Ludwig Canal		1.29 „ 1.75	1.16 „ 1.45	„ „
Canals on the left bank of the Ems	100	0.25 „ 1.25	0.20 „ 1.00	Canal belonging to a syndicate.
Average tariff on Navigable Ways in Germany		0.25	0.20	According to Sympher.
Canal from Dortmund to Ems and the Mittelland Canal	651	0.60	0.50	State canals projected and in course of construction. Tolls in consideration as proposed by the engineer F. GECK. „Mittheilungen des Vereins, January 1894."
Austria.				
Danube-Oder Canal	274	1.66	1.33	Projected canal. Average tolls in consideration. „Mittheilungen des Vereins, November 1893.

Calculation of Navigation Dues according to the following tariff:

1. **Fixed** toll of 10 centimes or 10 pfennings per ton paid for each journey by all vessels loaded or empty.
2. Toll paid by loaded vessels in proportion to the number of tons transported varying with the distance traversed in the following manner:

Toll per kilometric ton in centimes or pfennings.

	Raw materials	Other merchandise
Up to 50 Kilometres	0.40	0.60
from 50 to 100 Kilometres	0.35	0.55
" 100 " 150 "	0.30	0.50
" 150 " 200 "	0.25	0.45
" 200 " 250 "	0.20	0.40
" 250 " 300 "	0.15	0.35
" 300 " 350 "	0.10	0.30
" 350 " 400 "	0.05	0.25
" 400 " 450 "	0.05	0.20
" 450 " 500 "	0.05	0.15
" 500 " 550 "	0.05	0.10
" 550 " 600 "	0.05	0.05

Distance traversed in Kilometres	Toll per ton.		Total toll for a vessel of 400 tons fully loaded.		Toll per kilometric ton.	
	Raw Materials.	Other Merchandise.	Raw Materials.	Other Merchandise.	Raw Materials.	Other Merchandise.
	francs or marks.	francs or marks.	francs or marks.	francs or marks.	centim. or pfen.	centim. or pfen.
25	0.2000	0.2500	80.00	100.00	0.800	1.000
50	0.3000	0.4000	120.00	160.00	0.600	0.800
75	0.3875	0.5375	155.00	215.00	0.516	0.716
100	0.4750	0.6750	190.00	270.00	0.475	0.675
125	0.5500	0.8000	220.00	320.00	0.440	0.640
150	0.6250	0.9250	250 00	370.00	0.417	0.617
175	0.6875	1.0375	275.00	415.00	0.393	0.593
200	0.7500	1.1500	300.00	460.00	0.375	0.575
225	0.8000	1.2500	320.00	500.00	0.355	0.555
250	0.8500	1.3500	340.00	540.00	0.340	0.540
275	0.8875	1.4375	355.00	575.00	0.323	0.523
300	0.9250	1.5250	370.00	610.00	0.308	0.508
325	0.9500	1.6000	380.00	640.00	0.292	0.492
350	0.9750	1.6750	390.00	670.00	0.278	0.478
375	0.9875	1.7375	395.00	695.00	0.263	0.463
400	1.0000	1.8000	400.00	720.00	0.250	0.450
425	1.0125	1.8500	405.00	740.00	0.238	0.435
450	1.0250	1.9000	410.00	760.00	0.228	0.422
475	1.0375	1.9375	415.00	775.00	0.218	0.408
500	1.0500	1.9750	420.00	790.00	0.210	0.395
525	1.0625	2.0000	425.00	800.00	0.202	0.381
550	1.0750	2.0250	430.00	810.00	0.196	0.368
575	1.0875	2.0375	435.00	815.00	0.189	0.354
600	1.1000	2.0500	440.00	820.00	0.183	0.342

20

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

6th QUESTION.

Connection between the depth of streams and river beds.

BY

R. JASMUND,
Inspector of the Waterworks at Magdeburg.

THE HAGUE,
Printed by Belinfante B[ros], late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

VI^th International Inland Navigation Congress.

THE HAGUE, 1894.

Connection between the depth of streams and river beds.

BY

R. JASMUND,

Inspector of the Waterworks at Magdeburg.

PART I.

Notes on studies relatively to bends and depth. Distances between great and small bends and great and small depths. A graphical experimental method showing synoptical bends and diagrams of depths. Influence of width and water quantities on small depths near bends.

The study as to the connection between bends and depth of the stream is difficult for the river Elbe. It gives but little occasion to be studied in the same manner as Mr FARGUE did for the Garonne, as this river from the Gironde to Barsac, where these observations have been made, is made regular by embankments along its shores and therefore shows more precisely the proportion of its curves. The Elbe in the State of Prussia has banks that do not always follow the natural course of the stream and therefore suppositions can only be made on its bends. Riversides can change even with banks as this depends on their force of resistance. The more or less advanced position, even a few decimetres, can change notably a bend. Often they depend on wharves, quays etc.

The line of the current will not be influenced by these irregularities, its direction being pushed towards the middle of the curve. Changes in direction of the stream can be regulated by the depth of the water but the position of the line of the stream is more variable and unknown than its shores.

Circumstances that have effect on the movement of riverbeds and on depths of rivers.

The qnestion „where does the riverbed find its real course"? gives way to hesitations. The banks along the Elbe reach above the water

only a little at its average height, and form borderings for the water to about two metres above ebb, that is about 3 metres above the highest point of its bed. From 2 to about four metres above ebb the stream reaches to its ancient embankments which show themselves quite different in certain curves than with the corrected banks. The whole mass in its diversion is about the same, but different in certain parts inward of the curve.

It could be thought that on account of the great force of an overflowing river the influence would show itself not only on the corrected embankments but also on the depth and its ancient limits. These thoughts come back when we see high tides during which the water rises sometimes to $6^1/_2$ metres above ebb and innndates the surrounding shores two to three metres deep.

The strength of the current is greatest during high tide, the pression at its utmost and the bed of the river easiest worked. At these moments the water goes up to the dikes which have rarely the same direction as the corrected embankments. When the water follows the upper grounds along the dikes it crosses the real riverbed at different points and also on a different proclivity. In the curves the two streams will meet, but in other passages great deviations will take place. If it be accepted that the direction of the stream changes the riverbed it must also be admitted that the upper layers of water have influence on the under depths and consequently increase or diminish the depth of the river.

During high waters the fall of the riverbed changes as well in width as in depth, and varies in length in certain parts proportionately to the depth of the middle. It becomes so much greater as the depth is great in width at curves and in the middle of the stream. The width of the traverse profile or the depth of the channel have less influence on the fall as the middle depth. These notes are not taken from theory but from practical observations and these lead to proclaim that the fall of the river can change at different depths and if the direction of the middle stream changes. These changes are also greatly different and sometimes quite opposite with high water and that on account of irregularities in width.

In consequence the fall of a river depends on the height of water.

The profile in length is also more or less influenced when high waters pass over high beds. The surface of the water will not be more elevated in the concave part than in a convex part, this is often the contrary.

High waters have influence on the formation of riverbed by the different form of the fall but this also depends on the height of the water. These influences of high waters on the formation of the channel can be observed regularly on the different profile shapes of the Elbe. It is also proved that the advanced constructions in a river have influence on the depth of the channel. The relation between the correc-

ted and primitive riverbeds depend on subordinate powers and cannot be considered with certitude; few examples exist where small distances could serve as guide.

Choice of a place to study.

The time given to make this report was too short to examine the 485 kilometres, this being the length of the Elbe subject to the surveyance of the State of Prussia. It was therefore necessary to choose a distance and this abridgement was inevitable the whole course of the Elbe being inconvenient for such a study.

The channel on the distance chosen, 175 kilometres is not straight but has continual curves. The sand banks through which the river passes move in following the course of the stream or balance from one side to the other. These are the hazards on which depend the regulation of the fall of the bed, the direction of the current and the depth of the channel. Sand banks in continual movement! Although the study of these moving matters is interesting there can be no question of this in the present in this search.

Between Dessau and Havelmundung the channel is rather regular, the river making but few curves and this part does not present so much interest to be studied as the distance from the Saxon and Prussian frontiers untill above Dessau. On this distance of 145 kilometres chosen to be studied, the Elbe is generally regularised by banks and only in some parts by heightened shores. The width of the river is:

1)	from	120.8 kilometres	to	198.5	kilom.:	100 metres
2)	„	198.5	„ „	233	„ :	110 „
3)	„	233	„ „	259.5	„ :	130 „
4)	„	259.5	„ „	290.7	„ :	150 „

The width in the curves is about the same as the attaining parts. The original form of the corrected river line is rich in curves of all kinds. Some of these present a deviation of more than 180 degrees. Small passages, sharp bends, arcs and straight lines are found often together; these have had to be taken in consideration for the construction and excavation of the bed with idea of their position and utility. The high waters are kept back by the dikes which have been regulated or advanced in different directions since they have been built 50 or 60 years ago. The depths of the navigable channel are very different, but still do not go above 4 to 5 metres during low water. The water has:

1) during the lowest water, that is + 0.20 at the watermark at Torgau = about 0.60 cubic metres.

2) during average water, that is + 1.4 metres at the watermark at Torgau = 275 cubic metres.

3) During ordinary high spring water, that is + 6 metres at the watermark at Torgau = 2000 to 2500 cubic metres.

4) During the highest water of September 1890, that is + 7.40 metres at the watermark at Torgau = 4450 cubic metres.

The ordinary fall of the bed is 0.000272 per metre.

The river gives in the upper part, sandy earth and subsequently gravel.

The means of study.

The means to study the connection between the primitive bed of the river and the navigable channel can be taken from the map of the Elbe containing the corrected lines, scale 1 : 5000 and also series of sounds of different years.

These are of recent date and permit to see the curves of certain parts of the current. In drawing on transparent paper raduises of different sizes and fitting these on the maps of the river, the sizes and development of some of the curves.

The primitive riverbed, by this experiment, seems to be composed of straight lines and curves.

In reality this manner of compositing has only in a few cases the preference. Practical rules or precise instruction for the distribution of a curve do not exist for the Elbe. The corrected lines follow the primitive plan in their cut; the spaces among one another are disposed between different curves in the same circle according to the sight of the outline. An effort seems to have been made to avoid straight lines especially when these were between two curves in the same direction as experience shows. that on these points the current has a tendency to wind and form bad passages. Another effort consists in avoiding as much as possible circular curves when the position allows it without making too much expense.

It must also be considered that embankments must not be constructed too low otherwise they have not weight enough and also that the corrected shores must be paralell to these. The embankments must be as much as possible of the same height.

These different considerations give to the primitive bed different changes and forms that are difficultly demonstrated by circles. Notes on curves can only be obtained by measurements on the discussed places and this has been impossible on account of the want of time. But still to be able to fill this first and important condition a space of the river of 3.66 kilometres in length full of changes in direction has been chosen; notes have been made on three bends following one another. These notes are taken from the middle stream. As to the depth of the channel the measurements have been taken by sounds. Yearly since 1883 these have been made during low water by Stecher's sounding instrument on the whole course of the Elbe. This instrument has been described in the Centralblatt der Bauverwaltung in 1886; this is how it is composed.

A double armed lever is fixed between two boats tied together; one arm is long and has a cycloid form which drags on the bed of the river, while from the other arm a role of paper unfolds itself and notes the depth of the water. The scale of reduction for the depth is 1 : 50 and is conform to the length of the lever arm.

The measure of the length depends on the speed of the movement of the boats and of the unfolding of the role of paper. This varies between 1 : 3000 and 1 : 5000. From distance to distance 2 to 500 metres fixed points are noted on the paper role, for instance, corners of shores, pillars, etc.; by a special mechanism to register these marked places.

As to the soundings some of the most important during low water have been chosen.

Here are 5 examples.

N°.	DATE.		Height of water at the watermarks.		
			Mühlberg.	Torgau.	Wittenberg.
1	September	1883	1,07	0,66	1,10
2	August	1885	0,60	0,27	0,62
3	October	1887	0,66	0,34	0,46
4	November	1889	1,02	0,81	1,35
5	August	1892	0,63	0,25	0,67

At each distance of 50 metres a sound was taken and noted on a table. Thus for the 5 sounds of 145 kilometres an evaluation of 14500 sounds was taken. Of the 5 measurements on each point the average was noted. No reduction was allowed for fixed waters, the original measurements have remained without being changed.

Therefore the average depths of the channel are not based on the lowest but on the average position of the low waters.

The average deepest measurements do not perhaps give the real greatest depths but a little less. It is not possible to convey the instrument always on the deepest parts of the channel although the greatest precautions were taken. Sometimes the instrument follows the convex sand embankments too near and at other times passes over the places of anchorage near the quays or else it crosses the passage a little above or under the current. These irregularities are possible in some cases. Therefore the average of five different sounds were taken.

The depths found were graphically noted, the surface of the water taken as horizontal. The measures of the length 1 : 20000, height 1 : 20.

If any analogy existed between the depth of the channel and the

curve of the middle stream it would have been proved when these measures were noted. The size of the curve being proportionate to the contrary value of the radius and to avoid to write decimal the following way of calculation was used.

$$c = \frac{1000}{r}$$

and the depth found was noted. If the concave form was on the right or left the value of c was written down underneath or above the horizontal.

The following diagram of curves and depths in the Elbe from Muhlberg to Rosslau 121 to 266 kilometres was the result.

Fargue's precept.

In the Annales des Ponts et Chaussées of the year 1868 page 49 Mr. Fargue proposed 6 precepts for the comparison between curves and the line of middle stream and the depth of the channel; these will be examined.

I. Precept of digression: The great and small depths are found under great and small curves.

In a treatise published by the „Annales des Ponts et Chaussées" in the year 1882 page 315 Mr. Fargue gave the measure 2 l, that is the double width of the passage of the stream, at places where the river is more or less deep up stream of corresponding great or small curves.

A well known fact results from the diagram of synoptical curves and depths that greater depth is found in a bend than in the straight lines or these were the bend begins. A reduction of the depth is found on the right side between two curves having the same direction. That is why Mr. Fargue fixed points of inflexion and surflexion next to one another.

If the parts of the current are divided where in the diagram the curves k seem null, and these divided parts considered as being the smallest curves, the result of the diagram is that the parts where the smallest depths exist have undergone a displacement towards the upper part of the current. But still great differences exist for some.

In 97 cases 7 have undergone a displacement towards the upper current to an extent of 110 mètres; and 4 have undergone comparatively no displacement. With the 86 remaining cases a displacement can be noted downwards the current to an extent of 595 mètres. Ten of these have undergone a displacement of more than 400 mètres and even in these cases it is apparent that this great extent is yet divided.

But in examining on the precise part of the divided parts under the point of the tangent no accord is found. It is hoped that these irregularities will be effaced by the expression of averages of the following table.

TABLE no. I. Displacement of the greatest and smallest depths at the greatest and smallest curves.

Number.	Distance from kilomètres.	Distance to kilomètres.	Length (distance).	Displacement of smallest depth.	Displacement of greatest depth.	Length (straight line).
1.	120,80	122,65	1850	+ 595	+ 470	710
2.	122,65	123,47	820	+ 290	+ 310	
3.	123,47	125,10	1630	+ 545	+ 730	700
4.	125,10	126,10	1000	+ 60	+ 30	360
5.	126,10	127,55	1450	— 20	+ 260	140
6.	127,55	129,25	1700	+ 190	+ 400	140
7.	129,25	130,35	1100	+ 350	+ 60	320
8.	130,35	131,50	1150	+ 240	+ 40	200
9.	131,50	132,50	1000	+ 200	+ 90	240
10.	132,50	133,50	1000	+ 280	+ 140	200
11.	133,50	133,90	400	+ 90	—	210
12.	133,90	135,70	1800	+ 270	+ 300	480
13.	135,70	136,40	700	+ 225	+ 280	160
14.	136,40	137,03	630	+ 440	+ 220	90
15.	137,03	137,40	370	+ 75	0	140
16.	137,40	138,55	1150	+ 240	+ 270	0
17.	138,55	140,45	1900	+ 185	+ 130	370
18.	140,45	141,20	750	+ 120	+ 150	490
19.	141,20	143,35	2150	+ 260	— 125	240
20.	143,35	144,55	1200	+ 200	+ 200	260
21.	144,55	146,05	1500	0	— 130	240
22.	146,05	148,17	2120	+ 170	+ 190	210
23.	148,17	150,22	2050	+ 580	+ 300	250
24.	150,22	151,70	1480	+ 150	+ 300	290
25.	151,70	153,20	1500	+ 20	0	550
26.	153,20	154,48	1280	—	+ 250	990
27.	154,48	156,25	1770	—	—	—
28.	156,25	157,75	1500	+ 230	+ 330	710
29.	157,75	160,—	2250	+ 350	+ 250	400
30.	160,—	160,65	650	—	+ 230	500
31.	160,65	162,02	1370	+ 120	+ 440	200
32.	163,45	164,20	750	— 110	+ 350	260
33.	164,20	165,60	1400	+ 200	+ 290	70

Number.	Distance from kilomètres.	Distance to kilomètres.	Length (distance).	Displacement of smallest depth.	Displacement of greatest depth.	Lenght (straight line).
34.	165,60	166,65	1050	+ 220	+ 0	260
35.	166,65	168,45	1800	+ 50	— 60	380
36.	168,45	170,95	2500	0	+ 60	500
37.	170,95	173,35	2400	+ 210	+ 220	150
38.	173,35	174,00	650	+ 200	+ 300	150
39.	174,00	174,75	750	+ 120	0	170
40.	174,75	175,95	1200	+ 70	+ 140	120
41.	175,95	177,00	1050	+ 150	0	—
42.	177,00	180,25	3250	+ 110	0	0
43.	180,25	181,30	1050	— 80	— 40	170
44.	181,30	183,60	2300	— 60	0	510
45.	183,60	184,80	1200	—	—	—
46.	184,80	187,35	2550	+ 500	+ 300	—
47.	187,35	188,15	800	+ 450	+ 500	460
48.	188,15	188,95	800	+ 80	+ 280	390
49.	188,95	190,45	1500	+ 330	+ 370	550
50.	190,45	192,35	1900	+ 80	— 30	250
51.	192,35	193,30	950	+ 70	+ 90	230
52.	193,30	194,85	1550	+ 450	— 50	450
53.	194,85	195,50	650	+ 150	+ 120	0
54.	195,50	196,25	750	—	+ 270	1060
55.	196,25	198,45	2200	+ 380	+ 440	660
		1—55:	***average:***	+ ***201***	+ ***187***	
56.	198,45	200,80	2350	+ 260	+ 100	320
57.	200,80	202,70	1900	+ 380	—	0
58.	202,70	204,15	1450	+ 340	+ 250	0
59.	204,15	205,90	1750	+ 130	—	0
60.	205,90	207,10	1200	+ 180	+ 280	0
61.	207,10	208,05	950	+ 270	+ 420	250
62.	208,05	209,00	950	+ 230	+ 200	550
63.	209,00	210,15	1150	+ 300	—	110
64.	210,15	211,40	1250	+ 250	+ 260	260
65.	211,40	212,05	650	+ 300	+ 320	520
66.	212,05	213,85	1800	+ 420	+ 320	400
67.	213,85	214,90	1050	— 60	+ 300	590
68.	214,90	215,95	1050	+ 130	—	180

Number.	Distance		Length (distance).	Displacement.		Length (straight line).
	from kilomètres.	to kilomètres.		of smallest depth.	of greatest depth.	
69.	215,95	217,25	1300	+ 230	+ 260	—
70.	217,25	219,50	2250	+ 120	+ 0	0
71.	219,50	221,90	2400	+ 100	— 160	0
72.	221,90	223,55	1650	+ 200	+ 270	0
73.	223,55	225,90	2350	+ 260	+ 260	320
74.	225,90	227,80	1900	+ 0	+ 410	200
75.	227,80	229,60	1800	+ 210	+ 0	210
76.	229,60	230,60	1000	+ 380	+ 210	270
77.	230,60	231,80	1200	+ 400	+ 560	0
78.	231,80	233,85	2050	+ 300	+ 200	340
		56—78:	*average:*	+ *232*	+ *235*	
79.	233,85	236,00	2150	+ 110	—	500
80.	236,00	238,05	2050	+ 360	+ 320	160
81.	238,05	239,35	1300	—	+ 350	810
82.	239,35	240,30	950	+ 300	+ 400	210
83.	240,30	241,65	1350	+ 120	— 260	580
84.	241,65	243,25	1600	+ 190	+ 60	460
85.	243,25	245,85	2600	— 90	+ 150	620
86.	245,85	247,85	2000	— 20	+ 280	0
87.	247,85	250,00	2150	— 290	+ 340	180
88.	250,00	251,45	1450	+ 250	+ 150	400
89.	251,45	252,25	800	+ 50	+ 220	0
90.	252,25	253,30	1050	+ 430	+ 260	0
91.	253,30	253,90	600	+ 440	+ 430	410
92.	253,90	254,50	600	+ 290	+ 260	0
93.	254,50	255,30	800	+ 300	+ 290	160
94.	255,30	255,70	400	+ 200	+ 120	0
95.	255,70	256,40	700	+ 310	+ 300	180
96.	256,40	258,05	1650	+ 250	—	840
97.	258,05	259,25	1200	+ 200	+ 260	300
		79—97:	*average:*	+ *221*	+ *231*	
98.	259,25	260,10	850	+ 300	+ 280	180
99.	260,10	260,95	850	+ 280	+ 390	—
100.	260,95	261,75	800	+ 370	+ 360	240
101.	261,75	263,25	1500	+ 80	+ 470	630
102.	263,25	264,75	1500	+ 80	+ 420	350
103.	264,75	265,45	700	+ 50	— 180	200
		98—103:	*average:*	+ *193*	+ *290*	
	1—103: general average:			**211,2**	**211,0**	

It is curious to notice that although great differences in the measurements exist, the average gives nearly exactly the double width of the river 211,2 kilometres. On the distance above 121 kilom. to 198.5 kilom. the width is 100 metres while the distances between 1 and 55, the distance of displacement of the smallest depth is 201 metres, thus also the double width of the river. From 198.5 kilom. to 233 kilometres the width is 110 and the displacement 232 kilometres. Therefore the essays prove that the average approaches the double width. The same comparison may be noticed in considering the relation between the greatest depth and the greatest curve. Also from the middle point of the greatest curve to the extreme point of displacement, the distance of the greatest depth varies in some cases from — 260 to + 730 metres. The displacement down the current must also be taken in consideration. The average of 94 cases is 211 metres therefore as much as the average displacement of the smallest depth.

High waters that influence in some cases the regularity in the relation between the primitive depth of the stream and the depth of the channel have no more that influence in the mouth of a river.

The first precept of Mr. Fargue and a quantity of demonstrations show that the Elbe also endeavours to form at its smallest and greatest depth the double width below its smallest and greatest curve.

2) Loi de la Mouille: a large curve forms also greater depths.

Mr. Fargue declares that on the Garonne a great curve gives by a a similar function a great depth. But still in very long curves or very short ones there are exceptions. In order to try this rule for the Elbe the great curves have been grouped with great depths in following the order of their length in kilometres from 0 to 0.25, 0.25 to 0.50, 0.50 to 0.75 and so on.

The average was then taken for each group in order to see if really there existed any relation in these averages. The following table was formed to enable an easy examination.

TABLE n°. 2. Group of the great curves kilométriques $k_{(max^a)}$ and greatest depths $t_{(max^a)}$, in mètres showing the distance in kilom l, where the greatest depth is found.

	I.			II.			III.			IV.			V.			VI.		
	k	t	l	k	t	l	k	t	l	k	t	l	k	t	l	k	t	l
	0,14	2,02	1,20	0,40	2,20	1,63	0,67	2,38	1,00	0,78	1,24	0,40	1,05	2,29	1,00	1,33	2,18	1,15
				0,33	1,67	0,63	0,50	1,57	0,80	0,83	1,81	0,37	1,05	2,76	1,45	1,33	2,75	1,80
				0,25	1,46	1,77	0,58	2,36	0,65	0,85	2,67	2,15	1,10	3,02	1,10	1,33	2,53	1,48
				0,25	2,13	1,90	0,50	2,04	0,75	0,75	2,74	1,50	1,05	2,15	1,00	1,43	2,50	1,28
				0,45	1,96	1,15	0,68	2,12	0,95	0,83	2,10	2,53	1,05	2,68	0,75	1,43	2,81	1,50
				0,33	1,77	1,05	0,50	1,75	0,65	0,75	1,86	0,80	1,00	2,33	0,65	1,33	2,11	0,75
				0,40	2,90	0,70	0,66	2,16	1,20	0,88	2,15	1,90	1,05	2,50	1,80	1,33	2,55	1,05
				0,35	1,82	1,65	0,66	2,55	1,30	0,75	2,31	1,75	1,11	2,52	2,50	1,42	2,34	2,40
							0,70	2,58	2,00				1,15	1,93	0,65	1,33	2,20	1,20
							0,66	2,76	0,60				1,00	2,31	1,05	1,25	2,52	1,55
							0,67	1,98	0,85				1,00	2,20	3,25	1,44	2,13	1,45
							0,67	2,64	0,70				1,18	2,45	2,30	1,33	2,20	1,80
													1,05	2,45	1,25	1,44	2,55	1,80
													1,11	2,11	1,05	1,33	2,64	1,35
													1,00	2,13	1,30	1,44	2,67	0,60
													1,00	2,18	2,15	1,33	3,04	0,80
													1,00	2,40	0,40	1,42	3,28	0,85
Average:	0,14	2,02	—	0,34	1,99	—	0,62	2,24	—	0,80	2,11	—	1,06	2,38	—	1,37	2,53	—

	VII.			VIII.			IX.			X.			XI.			XII.		
	k	t	l	k	t	l	k	t	l	k	t	l	k	t	l	k	t	l
	1,55	2,53	2,05	1,82	2,27	1,85	2,00	3,32	0,82	—	—	—	2,50	2,82	1,15	2,85	2,74	0,70
	1,55	2,98	1,37	1,82	2,81	1,50	2,22	2,77	1,70				2,50	2,71	2,25	2,85	2,76	1,90
	1,52	2,52	1,05	1,82	2,39	2,12	2,00	2,55	1,20				2,50	2,80	1,65	2,85	3,19	2,05
	1,52	2,50	0,95	1,80	2,55	1,43	2,00	2,62	2,25				2,50	2,88	1,90	2,85	3,20	1,05
	1,66	2,63	2,40	1,82	2,27	0,95	2,22	2,74	1,40				2,50	2,36	1,00	2,85	3,02	1,50
	1,66	2,54	0,95	1,83	2,52	2,20	2,00	2,56	0,75				2,50	3,30	2,05			
	1,66	2,89	1,60	1,83	2,79	0,80	2,00	2,25	2,35				2,50	2,50	2,15			
	1,66	2,58	2,60	1,83	2,38	1,50	2,00	2,52	1,20				2,50	3,40	1,45			
							2,00	2,22	2,35									
							2,22	2,77	0,80									
							2,00	2,95	1,20									
Average:	1,60	2,65	—	1,82	2,50	—	2,06	2,67	—	—	—							

This document points out actually that with great curves the depth increases also. But the relation is not so significative as in certain cases differences exist. M. FARGUE found degressions also in his table for the Garonne. For the normal reconciliation of this theme he expresses a term of third degree. To determine a mathematical élocution as the average pronounced comparison, for the Elbe, the straight line would seem more correct than the conic section.

The incertitude is still greater if instead of taking the average, each result in the table is chosen separately.

Mr FARGUE found a reason for these differences and founded there on his third precept.

3. To the advantage of depth a curve must not be too long neither too short.

In accordance with this precept he found that the average of 1330 metres is in proportion with the middle length chosen.

For the Elbe in the 103rd division the average is of 1404 metre; in consequence the difference with the Garonne is not great.

But the influence of the distance l on the digression of the greatest average depth has not been shown here. The length of the curve seems to be equal for the small depth of the channel. There seem to be other reasons: for instance the distance of the current from the dike or the crossing of the current with the one of the tide or the direction of the river bed.

As for the Elbe the studies can be resumed as follows: that the channel is so much more deep as the current is strong at curves.

If the third precept be based on the idea that for the formation of a riverbed too long or too short curves must be avoided so that the necessary depth remains unchanged it would be supposed that during the enterprise to regulate a river all would be done to avoid unnecessary depths and no efforts would be made to obtain necessary depth.

4. Loi de l'angle. The extreme angle of the final tangent of a curve, divided by the length of the curve gives the average depth of the curve formed by the river.

To use this precept for the Elbe it would be necessary to take by a graded transporteur the diversion of the middle line, the extreme angle of the final tangent and the measurement in circle calculated as radius I This only value should then be divided by the width of the stream, and add the result to the middle depth and the divided width.

In dividing this combination again in separate groups of 0 to 0.25, 0.25 to 0.50, 0.50 to 0.75 each group becomes an average value, which resolves the existing relation. A graphical application of the essays and average produces will be found here after to facilitate conclusions and to enable an opinion to be formed.

TABLE n° 3: Group of the average curves k_m and where the average depths are found t_m.

	I.		II.		III.		IV.		V.		VI.		VII.		VIII.		IX.	
	k_m	t_m	k_m	t_m	k_m	t_m	k_m	t_m	k_m	t_m	k_m	t_m	k_m	t_m	k_m	t_m	k_m	t_m
	0,215	1,863	0,400	1,671	0,700	1,918	0,770	1,835	1,148	1,746	1,371	1,844	1,526	1,856	1,841	2,106	2,069	2,421
	0,079	1,469	0,437	1,854	0,636	1,987	0,924	2,042	1,146	1,887	1,300	2,011	1,524	2,135	1,933	2,216		
	0,243	1,545	0,500	1,941	0,540	1,929	0,760	1,869	1,110	2,291	1,280	1,836	1,679	2,84				
	0,119	1,423	0,498	1,779	0,587	1,998	0,750	1,377	1,057	2,077	1,289	1,928						
	0,067	1,704	0,350	1,454	0,667	2,187	0,806	1,984	1,015	1,676	1,325	2,087						
	0,200	1,829	0,458	1,828	0,561	1,936	0,861	1,743	1,058	1,939	1,293	2,216						
	0,221	1,761	0,467	1,799	0,628	2,204	0,805	1,905	1,143	2,041	1,381	2,338						
	0,243	1,654	0,483	1,704	0,580	2,254	0,753	1,814	1,173	1,980	1,459	2,069						
	0,108	1,633	0,280	1,818	0,573	1,927	0,947	2,000	1,116	1,980								
	0,086	1,646	0,430	1,900	0,656	1,936	0,831	1,899	1,134	2,031								
	0,231	1,766	0,329	1,675	0,634	1,833	0,761	2,037	1,164	2,025								
	0,200	2,132	0,400	2,037	0,725	1,621	0,779	1,841	1,026	1,888								
	0,103	1,640			0,677	1,845	0,886	1,860	1,080	2,020								
					0,661	1,728	0,905	1,891	1,058	1,989								
					0,536	1,910	0,846	1,891	1,121	1,948								
					0,667	1,907	0,867	1,683	1,138	2,354								
					0,569	1,843	0,954	1,912	1,050	1,980								
					0,550	1,910	0,989	2,109	1,212	2,231								
					0,660	2,225	0,946	2,123	1,663	2,260								
							0,814	1,755	1,127	2,031								
							0,905	1,920	1,187	2,223								
							0,874	2,082										
							0,956	2,059										
							0,988	2,228										
							0,750	2,267										
Average:	0,163	1,697	0,419	1,788	0,618	1,952	0,837	1,925	1,115	2,029	1,337	2,041	1,576	2,091	1,887	2,161	2,069	2,421

This table shows that a similitude in the idea of the above precept does really exist. But still great differences can be found in the averages and especially in the simple produces. To use a mathematical expression for these produces, a simple linear form would express the idea better than the circular forms used for the Garonne. From these digressions which are often considerable the following conclusion would be justified: that high waters have more influence on great middle depths than on an average depth. It is easily explained that on a spot where a small depth exists the average middle depth is otherwise worked than in a sharp bend where strong waters heave up sands. One cannot expect great exactitude in these cases.

5. Loi de la Continuité. A profile of the valley of a river is only regularly formed if curves change repeatedly.

Each sharp bend is followed by a sharp reduction of depth. It has been shown by experiments made at Bordeaux in 1875 that the profile of a river fixes itself definitely in a bed when the curves change continually. There is no perceptible relation between the primitive form and the depth for a curved distance followed by straight line, as on account of continual changes of bends the result is for a reduction of a bend, a reduction also of the depth and an increase of a bend also an increase of depth.

The size of bends having been taken from spot to spot, these facts could not be verified on the Elbe and therefore the sudden changes exist in the diagram. However variations in the depth can be seen when the curves are abrupt.

For these reasons curves have been visited on the spot on a small irregular distance from kilometres 157.34 to 161.00, that is a distance of 3.66 kilomètres. On the right hand concave shore buoys were placed on the corrected line at equal distances; each buoy designed a measurement of the corrected line to the line of the stream.

If the measured declination 3 is indicated by e, the distance of the measured declinations 1 and 2 by a, the distance of 2 and 3 by b and the radius of the shore by r, we have then the abscinded secant:

1) $$(a + b) \cdot b = (2r + e) . e$$

and the curve of the middle line of the river of 100 metres width

2) $$k = \frac{1000}{r \pm 50}$$

The result of the combination of these two proportions

3) $$k = \frac{2000 \cdot e}{b \cdot (a + b) \pm 100e - e^2}$$

That curve is efficacious for a distance of $^1/_2$ $(a + b)$ that is from the middle from above to the middle distance from the shore.

The results of measurement and reckonings are as follows.

A double armed lever is fixed between two boats tied together; one arm is long and has a cycloid form which drags on the bed of the river, while from the other arm a role of paper unfolds itself and notes the depth of the water. The scale of reduction for the depth is 1:50 and is conform to the length of the lever arm.

The measure of the length depends on the speed of the movement of the boats and of the unfolding of the role of paper. This varies between 1 : 3000 and 1 : 5000. From distance to distance 2 to 500 metres fixed points are noted on the paper role, for instance, corners of shores, pillars, etc.; by a special mechanism to register these marked places.

As to the soundings some of the most important during low water have been chosen.

Here are 5 examples.

N°.	DATE.	Height of water at the watermarks.		
		Mühlberg.	Torgau.	Wittenberg.
1	September 1883	1,07	0,66	1,10
2	August 1885	0,60	0,27	0,62
3	October 1887	0,66	0,34	0,46
4	November 1889	1,02	0,81	1,35
5	August 1892	0,63	0,25	0,67

At each distance of 50 metres a sound was taken and noted on a table. Thus for the 5 sounds of 145 kilometres an evaluation of 14500 sounds was taken. Of the 5 measurements on each point the average was noted. No reduction was allowed for fixed waters, the original measurements have remained without being changed.

Therefore the average depths of the channel are not based on the lowest but on the average position of the low waters.

The average deepest measurements do not perhaps give the real greatest depths but a little less. It is not possible to convey the instrument always on the deepest parts of the channel although the greatest precautions were taken. Sometimes the instrument follows the convex sand embankments too near and at other times passes over the places of anchorage near the quays or else it crosses the passage a little above or under the current. These irregularities are possible in some cases. Therefore the average of five different sounds were taken.

The depths found were graphically noted, the surface of the water taken as horizontal. The measures of the length 1 : 20000, height 1 : 20.

If any analogy existed between the depth of the channel and the

N°.	Designation of shores.		Kilo-mètres.	*a*	*b*							
40	Before the foundery at Dömitz.	2*a*	160,024	58	59	+ 3,00	+ 0,909	160,051	59	+ 53,63	+ 1,072
41	„ „ „	3	160,078	59	59	+ 4,12	+ 1,246	160,106	55	+ 68,53	+ 0,892
42	„ „ „	3*a*	160,133	59	59	+ 1,78	+ 0,525	160,159	53	+ 27,82	+ 0,784
43	„ „ „	4	160,185	59	50	+ 2,48	+ 0,955	160,209	50	+ 47,75	+ 0,917
44	„ „ „	4*a*	160,232	50	66	+ 3,23	+ 0,882	160,264	55	+ 48,51	+ 0,644
45	„ „ „	5	160,296	66	122	+ 5,60	+ 0,501	160,356	92	+ 46,09	+ 0,398
46	„ „ „	6	160,416	122	73	+ 2,12	+ 0,302	160,452	96	+ 28,99	+ 0,274
47	„ „ „	7	160,488	73	65	+ 1,04	+ 0,235	160,520	68	+ 15,98	+ 0,087
48	„ „ „	8	160,552	65	85	— 0,32	— 0,050	160,594	74	— 3,70	— 0,139
49	„ „ „	8*a*	160,636	85	80	— 1,47	— 0,220	160,676	82	— 18,04	— 0,294
50	„ „ „	9	160,715	80	53	— 1,97	— 0,351	160,796	120	— 42,12	— 0,466
51	„ „ „	10	160,876	53	100	— 4,48	— 0,569	160,931	135	— 76,82	
52	„ „ „	11	160,985	100	103	— 21,43	— 1,896				

The graphical exposal of these mathematical experiments shows that the shore in that part is quite irregular, as it has already been said, chosen expressly for this study.

The irregularities are local when great curves follow one another in direct and contrary way. Some are provoked by the irregular construction of the shores, embankments too high or too low, and others on account of the repeated changes of the bends. In the mathematical exposal the levelling deviation of the curve is shown and the union of the two bends that follow.

As it can be seen at first sight on the graphical reproduction a symetry exists between the changes of curves and the depth of the channel.

An increase of the curve shows an increase of the depth and a decrease of the curve also a decrease in the depth. In consequence the precept given above is confirmed here. Also the precept of displacement is found here again with more regularity than in the preceding table. The distance of displacement varies between + 150 and + 320 with an average of 227 metres.

6. Loi de la pente du fond. The tangent of a curve kilometrique determines for the fall of the bed.

With an increase of a curve, an increase of the depth is the result and vice versa.

For the Elbe no other examples can be given as the other curves are unknown.

Between the size of the tangent q and the fall p the following proportions exist:

Curves kilometres.					Depth of channel				
Station.	Curves Kilometres. k	Difference of the curves. δ	Length of distance. $l_{,}$	Tangent $q = \frac{1000\ \delta}{e_{,}}$	Station.	Depth of channel. t	Length of distance. $l_{,}$	Difference in depth. d	Fall of the bed. $p = \frac{1000\ d}{e_{,}}$
157,56	0				157,75	1,38			
158 03	2,15	2,15	470	4,58	158,25	2,10	500	0,72	1,44
158,45	0,55	1,60	420	3,81	158,65	1,57	400	0,53	1,33
158,78	2,40	1,85	330	5,61	158,95	2,60	300	1,03	3,43
158,98	1,10	1,30	200	6,50	159,30	2,21	350	0,39	1,11
159,28	2,25	1,15	300	3,83	159,55	2,54	250	0,33	1,32
159,70	— 0,25	2,50	420	5,95	160,00	1,39	450	1,15	2,56
160,08	1,30	1,55	380	4,08	160,30	2,19	300	0,80	2,67
160,50	0	1,30	420	3,09	160,65	1,71	350	0,48	1,37

In general there is an increase of p and q, with the exception of N°. 4 which gives $q = 6.50$ and $p = 1.11$. For the others an increase or decrease of the curves give increase or decrease of depth and fall.

The supposition of a relation in that sense comes from that comparison although the examples do not precise in what way that relation exists. That similitude is a logical result of the above precept.

This study confirms in general the appreciations of Mr. Fargue. If differences exist they can be imputed on the difficulty of making serious observations on the Elbe.

Changes of the stream during low water.

Can it be proved that during low water in the Elbe there is increase of depth by the clearing of the sand?

Some observations have been made during several months in 1889 with low water at eight different places and by means of 2 to 3 sounds per week and with a graded level especially constructed for the circumstance.

In the following results the sounds show on one side the greatest height of the beds and on the other hand the average heights of the whole distance H. N.

TABLE no. 6. Height of water during ebb.

a. km. 131.3 to. 131,75

DATE.	Height at lowest level	Height in the channel above H.N.	
		greatest.	average.
16th July 1889	+ 1,06	+ 85,46	+ 85,20
18th " "	+ 1,33	+ 85,55	+ 85,17
20th " "	+ 1,42	+ 85,53	+ 85,15
23d " "	+ 1,13	+ 85,60	+ 85,08
25th " "	+ 1,03	+ 85,60	+ 85,00
30th " "	+ 1,13	+ 85,61	+ 84,96
2d August 1889	+ 1,55	+ 85,64	+ 85,16
6th " "	+ 1,38	+ 85,50	+ 85,16
9th " "	+ 1,06	+ 85,56	+ 84,99
13th " "	+ 0,97	+ 85,57	+ 85,07
16th " "	+ 0,86	+ 85,55	+ 85,06
21st " "	+ 0,86	+ 85,58	+ 85,12
24th " "	+ 0,86	+ 85,58	+ 84,97
27th " "	+ 0,78	+ 85,59	+ 84,99
30th " "	+ 0,84	+ 85,60	+ 85,03
2d September 1889	+ 0,89	+ 85.60	+ 85,02
6th " "	+ 0,77	+ 85,60	+ 84,99
11th " "	+ 0,71	+ 85,64	+ 85,05
13th " "	+ 0,71	+ 85,64	+ 85,04
17th " "	+ 0,71	+ 85,55	+ 84,96
20th " "	+ 0,74	+ 85,56	+ 85,02

b. km. 155,5 to km. 156,0

DATE.	Height at lowest level.	Height in the channel above H. N.	
		greatest.	average.
13th August 1889.	+ 0,52	+ 79,12	+ 78,90
16th " "	+ 0,48	+ 79.20	+ 78,90
20th " "	+ 0,50	+ 79,05	+ 78,90
23th " "	+ 0,48	+ 79,13	+ 78,93
27th " "	+ 0,40	+ 79,09	+ 78,88
30th " "	+ 0,38	+ 79,02	+ 78,88
3d September 1889. . . .	+ 0,46	+ 79,10	+ 78,92
6th " "	+ 0,38	+ 79,27	+ 78,91
10th " "	+ 0,32	+ 79,10	+ 78,89
14th " "	+ 0,34	+ 79,07	+ 78,88
17th " "	+ 0,36	+ 79,08	+ 78,90
21th " "	+ 0,38	+ 79,06	+ 78,89
24th " "	+ 0,44	+ 79,19	+ 78,91
28th " "	+ 0,76	+ 79,11	+ 78,93

c. km. 210,0 to km. 210,6

DATE.	Height at lowest level.	Height in the channel above H. N. greatest.	average.
27th August 1889	+ 0,76	+ 67,15	+ 66,88
30th „ „	+ 0,76	+ 67,03	+ 66,84
3d September 1889	+ 0,86	+ 67,10	+ 66,88
6th „ „	+ 0,75	+ 66,99	+ 66,87
9th „ „	+ 0,70	+ 67,19	+ 66,90
13th „ „	+ 0,66	+ 66,97	+ 66,77
16th „ „	+ 0,68	+ 67,04	+ 66,82
20th „ „	+ 0,70	+ 67,04	+ 66,78
23th „ „	+ 0,77	+ 66,86	+ 66,70
27th „ „	+ 1,00	+ 67,09	+ 66,80

d. km. 283,01 to km. 283,25

DATE.	Height at lowest level.	Height in the channel above H. N. greatest.	average.
19th August 1889	+ 0,62	52,14	52,05
21th „ „	+ 0,58	52,11	52,04
23d „ „	+ 0,59	52,10	52,02
26th „ „	+ 0,55	52,03	52,02
28th „ „	+ 0,48	52,05	52,01
30th „ „	+ 0,49	52,04	52,01
2d September 1889	+ 0,60	52,17	52,10
4th „ „	+ 0,55	52,17	52,10
6th „ „	+ 0,50	52,18	52,11
9th „ „	+ 0,43	52,17	52,11
11th „ „	+ 0,38	52,19	52,15
13th „ „	+ 0,38	52,25	52,16
16th „ „	+ 0,38	52,24	52,14
18th „ „	+ 0,38	52,25	52,13
20th „ „	+ 0,39	52,22	52,16
23d „ „	+ 0,43	52,22	52,15
25th „ „	+ 0,48	52,23	52,14
27th „ „	+ 0,54	52,24	52,14

e. km. 302,0 to km. 302,3

DATE.	Height at lowest level.	Height at the channel above H. N.	
		greatest.	average.
26th August 1889	+ 0,66	+ 48,83	—
28th „ „	+ 0,58	48,80	—
30th „ „	+ 0,58	48,73	—
3d September 1889	+ 0,61	48,70	—
5th „ „	+ 0,56	48,78	—
7th „ „	+ 0,56	48,81	—
17th „ „	+ 0,46	48,69	—
19th „ „	+ 0,43	48,73	—
21st „ „	+ 0,38	48,67	—
24th „ „	+ 0,57	48,66	—
26th „ „	+ 0,52	48,61	—
28th „ „	+ 0,62	48,64	—

f. km. 344,6 to km. 344,95.

DATE.	Height at lowest level.	Height in the channel above H. N.	
		greatest.	average.
27th August 1889	+ 0,66	40,07	39,55
29th „ „	+ 0,62	40,02	39,57
31st „ „	+ 0,62	40,07	39,60
3d September 1889. . . .	+ 0,66	40,07	39,55
5th „ „	+ 0,63	40,02	39,63
7th „ „	+ 0,58	39,94	39,54
9th „ „	+ 0,55	40,12	39,64
12th „ „	+ 0,47	40,08	39,47
14th „ „	+ 0,47	40,03	39,47
17th „ „	+ 0,45	40,01	39,48
19th „ „	+ 0,44	39,95	39,43
21st „ „	+ 0,44	40,05	39,50
24th „ „	+ 0,47	40,04	39,50
26th „ „	+ 0,50	40,06	39,49
28th „ „	+ 0,60	40,01	39,50
30th „ „	+ 0,78	40,02	39,53
2d October 1889.	+ 1,10	40,04	39,54
4th „ „	+ 1,60	40,02	39,54

g. km. 326,0 to km. 326,30.

DATE.	Height at lowest level.	Height in the channel above H. N. greatest.	Height in the channel above H. N. average.
22d July 1889	+ 1,20	44,14	43,98
24th „ „	+ 1,18	44,12	43,96
27th „ „	+ 1,04	44,11	43,97
29th „ „	+ 1,00	44,07	43,90
31st „ „	+ 1,04	44,05	43,89
2d August 1889	+ 1,04	44,08	43,92
5th „ „	+ 1,20	44,04	43,90
7th „ „	+ 1,18	43,99	43,86
9th „ „	+ 1,16	43,98	43,84
12th „ „	+ 1,00	44,01	43,84
14th „ „	+ 0,90	44,04	43,93
16th „ „	+ 0,96	43,98	43,87
19th „ „	+ 0,96	44,00	43,86
21st „ „	+ 0,92	43,96	43,82
23d „ „	+ 0,92	43,96	43,82
26th „ „	+ 0,92	43,96	43,81
28th „ „	+ 0,82	43,96	43,81
30th „ „	+ 0,86	43,97	43,82
2d September 1889	+ 0,90	43,94	43,81
4th „ „	+ 0,88	43,92	43,76
6th „ „	+ 0,86	43,90	43,77
9th „ „	+ 0,80	43,84	43,73
11th „ „	+ 0,74	43,78	43,70
13th „ „	+ 0,70	43,84	43,73
16th „ „	+ 0,74	43,85	43,70
23d „ „	+ 0,76	43,87	43,72
25th „ „	+ 0,80	43,81	43,68
27th „ „	+ 0,80	43,81	43,68
30th „ „	+ 0,96	43,90	43,67
2d October 1889	+ 1,16	43,87	43,68
4th „ „	+ 1,66	44,00	43,69

h. At Mödlicher Werder.

DATE.	Height at lowest level.	Height in the channel above H. N.	
		greatest.	average.
26th August 1889	+ 0,85	15,95	15,72
29th „ „	+ 0,85	15,96	15,75
2d September 1889	+ 0,75	15,91	15,66
5th „ „	+ 0,75	15,92	15,66
7th „ „	+ 0,75	15,92	15,67
9th „ „	+ 0,74	15,91	15,67
12th „ „	+ 0,67	15,85	15,60
14th „ „	+ 0,63	15,82	15,56
16th „ „	+ 0,62	15,86	15,58
19th „ „	+ 0,61	15,87	15,58
21st „ „	+ 0,63	15,88	15,61

Low waters deepen the bed very little, but still more on the lower parts of the river on account of the clearing of the sands. The variableness of the middle point of the navigable channel is greater than in its greater height. This has been shown by the sounds; the circumstances that occasion the difference is that during low water the banks of the bed are more perpendicular than during high waters. These banks concentrate the more when the fall is great the channel is more accentuated. With high water tbe banks form themselves less straightly and the channel is consequently less deep.

It may be that the depth of the channel is only apparent on account of the moving sands covering the declivities. At the mouth of the Elbe the constant movement of the sand banks can be easily seen. The forms of the current and shores show positively that at different places the sand banks go from one side to the other. During high waters the bed grows in height while with ebb tide the sand moves more slowly untill the turn of tide. That is how the movements of sand banks can be explained,

The dependence of the channel on the bed of the river shows itself distinctly. Although the current be regulated the bed of the river can be noticed amidst the sandbanks. The form is the same but the height of the sandbanks and the depth of the channel are sensibly reduced.

The resnlt gives occasion to compare on the distanee of the higher Elbe which has been observed, the channel existing at present and the one of the twentieth year of this century. Here also the depth is greater through the regulation of the width and sanding up of the channel. As this regulation took place by an increase of the shores the influence of the width on the lowest depth can be remarked.

It can be seen on the tables of synoptical curves and depth diagram of the Elbe that from the point 250 kilometres where the width commences to measure from 130 to 150 metres a greater depth exists than in tbe above part.

The numerous notes resulting from these studies as to the relation between the primitive form and the actual bed of the river give no exact measure and it is therefore necessary to continue the study more closely.

PART II.

Study on the measurements of a straight line and an arc forming together the primitive bed compared with a system proposed by M. Fargue. Influence of high and low waters on the depth of the channel near a tangent point. Maximum curves to be admitted for a channel composed of different widths and strength of current. Practical rule for the choice of a form for the bed of a river having a stream with or without tide.

Up to the present the study was limited to register certain facts and observations but hereafter the other points of the program will have to be discussed, the use of the knowledge to regulate the current. It passes therefore from a fixed ground to a speculative direction, where possibilities may have to be brought forward.

Mr Fargue says in his treatise, see Annales des Ponts et Chaussées year 1868, page 53.

The bottom between the channel and riverbed must be even.

According to the 6th precept of part I the kilometrical curve must be followed by a straight line which gives to the form „spiralvolute".

The spiralvolute as form of a river.

As introduction to this theme Mr. Fargue makes a supposition that the bed of the river has a form in volute.

In the Annales des Ponts et Chaussées of 1882 he exposes this proposal declaring that the width of a river is not constant but is greater in a curve especially at a sharp curve. He calls that form „la trace rationnelle."

These two conditions have no relation with one another, but come from different points of view. As to the volutal form as form of a riverbed the idea gives matter to reflection.

The supposition of a straight line inclined and the conclusion that the kilometrical curve changes from to point would make the curve appear

in zigzag where the refraction point would be on one side at the top and at the other end at the axe of the curved distance.

At that point of refraction a certain discontinuation (loi de continuité) which would not be conform to the 5th precept. The variability of the curve would have precisely at the most important point of the river no sudden change but would have a certain tendency to vary. Such changes in direction seem not be in accordance with the 5th precept that expresses constant changes, because in nature no direction changes suddenly. Even if the force existed the form from an increase to a decrease would not take place immediately, a certain length of time would be necessary to change the direction. If this force is wanting, a change in the depth is the result. The condition with which a continual change of a curve could take place would have to be that the tangent of a kilometrical curve, the top as well as the point of inflexion be horizontal. The curve would have to show a flowing in form of a sinus curve with minima and maxima values with vertical points. A continuation of a cut line does not seem to accord with the developed precept.

Another supposal against the form in spiral volute is brought by the size of a curve maxima. It has already been said when the 3rd precept was studied, that the regulating of a river would take place without trouble and that no special measures would have to be taken to obtain great depths. In one way the more the fall would be uneven, the more facility would exist to form and keep great depths. Instead of an average fall the bed would have to be formed in platform to obtain a strong current. On the other hand the forming of great depths prejudices the developement of width and a shortening of width occasions difficulties for the tide, the navigation and the clearing of ice. Sharp bends are not liked by navigators when the towing material has to be shortened.

When Mr Fargue in his trace rationnelle accepts the enlargement of the river in its bends, and that the width must be so much the larger as the curve is sudden, that acceptation is contrary to natural proportions. In reality the width is everywhere so much the smaller as the curve is great. All means employed to obtain an enlargement of a curve that is out of the reach of ebb and tide, are useless, many examples could be given if the fact was not generally known. A width in curves above the average has a prejudical effect in heaping sand on the banks and during low water there is want of current. The size of a maxima curve that Mr Fargue attains in choosing the spiral volute for the middle line, is the double of an ordinary bend in the same proportions. Its greatest depth would be greater and the width in reality smaller, which developement cannot be considered in any way as an improvement.

Another point which seems to weigh against the spiral volute, is the union of the prolongation of the passage of a curved distance into another. The curve diminues progressively untill extinction.

On the other hand the circular form becomes greater by half till a double length and then reduces again one half. The spiral volute loses its influence by its progressive march especially for average curves, because as it will be said hereafter there arrives a moment when the action of a curve is lost. A small curve has the same action in its influence as a straight line.

With strong or high waters that circumstance will not present itself so much, but it is not during high waters that the profile of a river changes, the changes of position and depth take place during low waters. Therefore the aim of stability is not attained.

Studies provoke even more to the use of a decrease in width. A prolongation of distance and an increase of curves bring in greater dragging and other expenses of construction.

Experimental Method.

The experiments made on small trenches in Bordeaux showed that the spiral volute tries to follow the natural course of the river while for curves and straight lines assembled no law of direction exists. But still these essays have no weight. The imitation of natural passages on a small scale encounters difficulties because the working of certain forces do not keep the same peculiar quality in a reduced scale. For instance quickened forces find an advantageous resistance with fine sand. If it be found necessary to reduce the fall, it is also impossible to produce firstly, the just proportion for the size of the gravel and secondly, to produce a force running exactly.

The absence of different speeds for different depths of water can also be added to what has been said. I have examined this question in my treatise in 1893 see „Zeitschrift für Bauwesen" on the ground of numerous measurements taken in the Elbe and I showed the probability that the speed of the water on the river bed is nearly nul and begins only a few centimetres higher.

The speed acquired in different depths is proportioned to their distance from the bottom, the scale of speed corresponds to the logarithmical line. The progression of speed in beginning at the bottom to the surface is quite different in deep or not deep water.

Very few cases exist where the speed remains the same in an extension of vertical depth.

But still this is the condition for the apparition of whirls and swells with vertical axe. I must give way to the conjecture that in the experiment made the whirl with vertical axe will take place only along the sides and not in the middle current as it does in reality.

The whirl is not a superfluous apparition, only in the above case, but it is the just form of movement by which the curve influences the depth.

Therefore it seems to me, that the model does not show the form of currents of water as it should do.

The origin of great depths.

The manner and means by which the current works on the curve of a river and on the depth of the channel is too important not to try to explain it as much as possible. It is unquestionable that the fall in curves is less than in a straight line. Also the continual change of direction weakens the force of the current. This taking away of moving forces does it not indicate also a reduction of depth? And still in reality the depth of a curve is so much greater as the curve is great.

In examining the current we learn that the most extraordinary depths are in general where whirl and swells exist. The whirl is not a finishing of the current, but simply a change in its direction and a diversion of its force.

A whirl is a force where the current at the entrance and going out meet together. No strength is lost or gained. It is developed by the force of one impulsion alone. Each swell can become a whirl in advancing in the direction of its axe. Then it takes away from the current more and more strength which is lost against the resistances of its surroundings and on its meeting the ground. This last is attained so much easier by its vertical position. The whirl gains strength in itself because the stream has a greater fall than in the current and consequently receives a greater impulsion.

The whirling movement with perpendicular axe tries to develope itself wherever it can.

A whirl or swell is formed by a certain force of water having the same speed and horizontal direction. The movement of a whirl must have forcibly its axe horizontally or perpendicular to the surface of the water. To obtain a whirl with vertical axe, considered at a point of view of an horizontal axe, the lines of same speed at the place of its transversal formation must show a vertical direction. In a large and even deep current it is impossible that a whirl can form itself, as here the flow can only take place in a horizontal line with same speed and the speed from the bottom to the surface becomes greater. The sounds show that generally near the shores the greatest speed exists not at the surface but under the water and often at a great depth. The same speed is found here disposed at more than 90 degrees against the surface.

There must exist in the transversal profile a point where these lines are turned to precisely 90 degrees in a vertical flow, at least in a certain extension. In the same way that the ground works at the reduction of the speed the nearer the stream is, the shores in their horizontal position work yet more on the near currents than on those further off.

What takes place for the bottom takes place also on the shores of a curve.

If the size of the gravel and the uneven bed has an influence, the different constructions advancing along the shores must also have their influence.

These questions are very unclear and it would be well that the Engineers examine these points and study the influence of the shores on the speed of the current to have answers to these important demands. The study of whirls is also bound to such inspections. That movement is not an exception for curves but is a rule; it is more developed and strong the sharper the curve is. The result is that the whirl is a means that the current uses to gain a greater depth.

The size of curves.

If considered at the preceding point of view depths appear under a different form. They do not make themselves but are the result of sacrificed forces of the current. These sacrifices are inopportune for the obtaining of useless depths as long as these same forces can be used to obtain useful depths. The measure of the smallest depth and not of the greatest is peremptory for the economical use of the current. It would be better if it were possible to obtain an equal depth for the whole channel to enable the forces of the current to be used as far as possible.

The precept of the first part shows that it is nearly impossible to obtain an equal depth for the whole stream. In curves the depth is greater and these cannot be avoided. But from the moment that the average depth is surpassed in curves, the over depth becomes useless. This increase of depth does not only use for their maintenance of useful forces of the current but is generally accompanied by reductions in the width and differences in the fall to the detriment of the course of the stream. The limits of a maximal curve have been fixed by precept 2 and above claims.

If a river be regulated in that order of ideas, once that the passage would be formed and corrected, measures could be taken in the sense of the size of curves. Subsequently it would be shown that small curves would suffice. In the first part entertaining on the studied distance of the Elbe, there exists at the smallest curves a maximal depth that is unnecessary in the best channel. If it were necessary to dig out the channel the same thing would not have to be done for the curved parts, each correction of a curve being followed by unknown circumstances. Even the smallest curve would correct itself after such a work. The small curves have the least favorable beds because the current has no certain direction. During high waters the current passing through small curves gains an uncertain gait. Small curves and advancements form

simply irregularities, the current passing along these passes in long and deturned strokes.

Curves must therefore be neither too long and curved distances must not be too short.

At a practical point there exist limits for curves. The consideration that there is interest in having as small curves as possible would lead to prefer straight lines. There can be nothing said against the principle if the river has a continued flow of water; but for rivers with tides it would be necessary not to occupy oneself with the average width but to obtain average curves. In curves of a river without tides the profile of the watercourse would not change much as the development of the convex shores is free. The channel would keep on the concave shore if the curve is not too short and no special surety would have to be taken during low waters. In straight lines the river would follow the bed of the current during low waters and leave its direction along the shores. The formation of the depth would depend on the form of its shores and to regulate for low waters would be found inefficace.

To avoid changes in the bed of the river and form one only current for low waters it would be necessary to build shores for low waters. Therefore it is necessary to regulate rivers with tides in straight lines for low waters. The construction would have rather a character of transformation than the limiting of the size of its profile. There is no necessity of transformation when in a current in straight line there are no accumulations of sand. But still in reality certain cases exist where exceptionnally such a construction of the profile for low waters has also a character of limiting.

As it has already been said in the first part, the Elbe shows at different places, although it has been regulated, the same accumulations of sand and the same direction of the river valley as existed before its regulation. Subsequently the formation of the bed depends on the height of water and surroundings in general. It is therefore necessary to examine these signs when regulating a river, but often no remedy can be brought in as the works must follow the shores.

In general the considerations of part I are not contrary to the regulations of rivers in straight lines. Here is an example of what has taken place in Switserland with straightened rivers: Mr von Salis, chief inspector writes as follows:

Dass Schweizerische Wasserbauwesen, Bern 1883 page 62.

„As a striking example this is what has been experienced in that way „(straight shores) among many other examples on the Plessur, near Thier.

„On a distance in straight line of one kilometre the bed has been „dug out during a terrible catastrophe 120 years ago and although the „banks have not been repaired as should be a strong current and „10 $^{0}/_{00}$ fall, the banks have not been damaged. The explanation of this

„can only be found in the well proportioned width and the current in „straight line."

In this case the shores for high water and those for low water are in the same direction. Where this is not the case and for natural rivers with irregular dikes, the construction of banks for low water are indispensable.

Also in curves hardly marked the necessity would perhaps show itself if the curve is small and the current has to be lead. The stream follows so much the easier the irregular shores when the water mass is small and not deep. A precise measure of curves can only be taken by a close examination.

The kind of curves.

The precept in part I gives although in another point of view still a decisive direction. The 6[th] precept (loi de la pente du fond) says that the fall of the bed depends entirely on the change of the curve. An increase of the curve indicates an increase of depth and vice versa; a smaller curve shows a smaller depth. The non variability of the curve shows a regular depth. In a circular curve the current should give a regular depth to the channel. According to the experiments made in trenches at Bordeaux the circular ways are very irregular but still they incline to form great depths. The Elbe has different circular curves; for instance the distance 56 on the diagram from kilometres 198.4 to 199.5, 1100 metres length there is no sign of any hollow formation, although the radius has 500 metres only and the diversion 174 degrees. The bed is nearly equal.

Even on irregular beds, the depths that are formed by a curve are generally greater than those of the current. The curve must not be so reduced that the current recedes and can no more be directed. In the same way that the regular depths have been described as the most useful, the circular curves define better the principle of regulation.

But nature does not show more circular curves than straight lines. The natural bed of a river winds in different continual curves and with different depths through the valley. It must be seen before the regulating of a river if the cost is not too high. For that reason one must not make circular curves. Also in large valleys one must abstain from uniting curves of different sizes.

The kilometrical curve must show a continued change and not a sharp one in order that the tangent keeps its sole value.

The formation of beds.

A riverbed formed of curves and straight lines or curves in different directions, would show at the uniting points sharp curves. The channel

would have constant changes in its depth. This would be the case when the straight line between two circles is short. According to the above rule, the large half curves and long curved distances should be used and the length of the passage decreased. In such a decrement a preference would be given to the distances made of curves and straight lines instead of the spiral volute. By the synoptical diagram of curves and depths it is not proved that from the passage of one curve into another there be a reduction of depth in the curve that follows. On the contrary it seems that the middle points between the long distances between small curves are exposed in their depth; for instance compare 215 kilometres and 223.35 or 187.35 and 180.4 kilometres or with 190.97 and following.

The banks cross the current in an inclined position and gather the sand banks. The more the waters retreat the more the accumulation continues. These form during the low waters trenches that clear more rapidly the water and the fall is slighter.

The passage becomes longer because the stream has not its primitive form of the middle passage, it is pushed aside by he accumulations, which is dangerous during low water because the current has a greater length. Where the current carries sand it makes barriers that the river keeps at different heights of water and the channel then winds very much. If it is found necessary to give a fixed bed to the current this remark will have to be taken in consideration and the channel for low waters must be cleared as much as possible and made to wind; otherwise the cause that the river winds must be taken away in clearing the accumulations.

The regulation of a river must have in view to shut the above part of the trench along the accumulation in order to leave to the current all its force for the real passage.

Regulating the width as Mr. Fargue proposes can only be approved for these reasons. The current in a great depth works on itself and is different to the one that loses its strength on the bottom. On the Garonne the passages are reduced to about $^1/_4$ of the width of the stream and therefore gain in depth. The result is also a reduction of the low waters which was very usefull in the radius of the tide but higher up could not be admitted. It would be impossible to retrench the Elbe in that way to the height of the average waters. If the result were to keep great depth for the passages, an increase of average waters and a reduction of low waters would follow. The passages rule low waters and the width, average waters.

The retrenchment should have in view a change for low waters but should not surpass these. This retrenchment would be the means of acquiring greater depth just as if there was question of regulating. The fall in the passage would be less and increased in the curve above. The increase of the fall in the curve above threatens an increase of the force for the forming of whirls and an increase of the fall in the curve which

should be stopped if the low waters do not decrease too much. The resistance that existed precedingly in the passage should be displaced to the curve. This can take place in filling up the great depth. In filling up the curve these will be less sanding up of the depth and an increase of width during low waters. As to the depth nothing will be changed as long as the whirling movement can be kept back. It can be examined also if it is not possible to contrary the movement of the whirl by a declivity of the concave shore. This can be realised as in strengthening the shores a same force of current can be given to the transversal profile.

To avoid great depths to be formed in curves seem to be closely united with a bettering in the formation of the riverbed.

As to the forming of the riverbed it must be noted that it is only after regulating that it is good to rule the average waters. But one must also keep account of expenses and navigation; advanced constructions might be a danger to navigation during low waters.

In certain cases different changes have to be made for the forming of regular riverbeds and the fixing of a minimal depth. In general the question cannot be exhausted.

PROPOSALS.

The following proposals are made on the basis of the preceding study.

I. *It is necessary to continue the study of the relation between beds of river and depths of channels. To this must be added the influence on depth of the advanced constructions and regulating works.*

II. *To keep the currents from winding it is necessary to build banks in a straight line for low waters.*

III. *To stop the channel from becoming too deep half diameter curves must be sufficiently large but not so large that the current loses its support on the concave shore.*

IV. *Curves in form of an arc are useful to obtain equal depths. If in such a bend different curves would become necessary on account of the place, the continuation of one curve into the other must not be too sharp.*

V. *To improve useful depths retrenchment of the width for low waters can be recommended and in the large curves a filling up of the too great depth.*

Inschriften der Zeichnungen.

Synoptisches Curven- und Tiefendiagramm der Elbe.

Rad (= Radius).

Inscriptions des Planches.

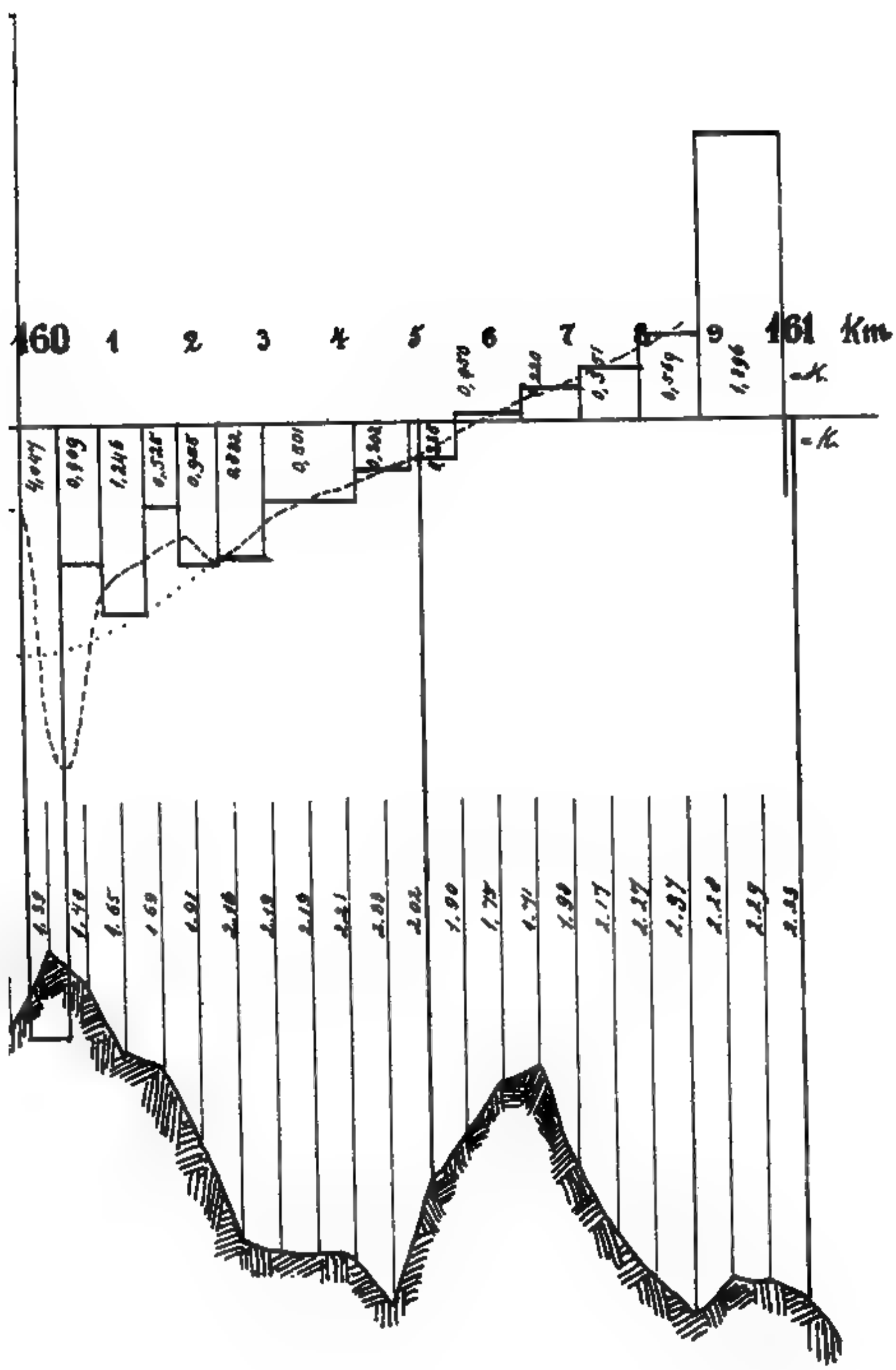
Diagramme synoptique des profondeurs de l'Elbe.

Rayon.

Description of the Plates.

Synoptic diagram of soundings on the Elbe.

Radius.

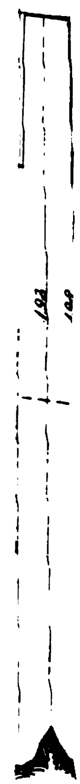


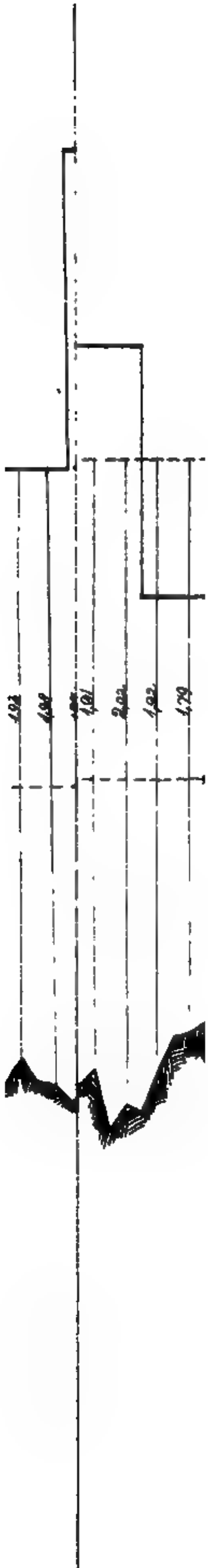
STEENDRUKKERIJ v/h AMAND, Amst.

I

S

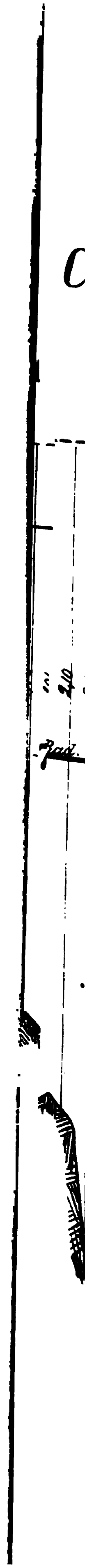
E

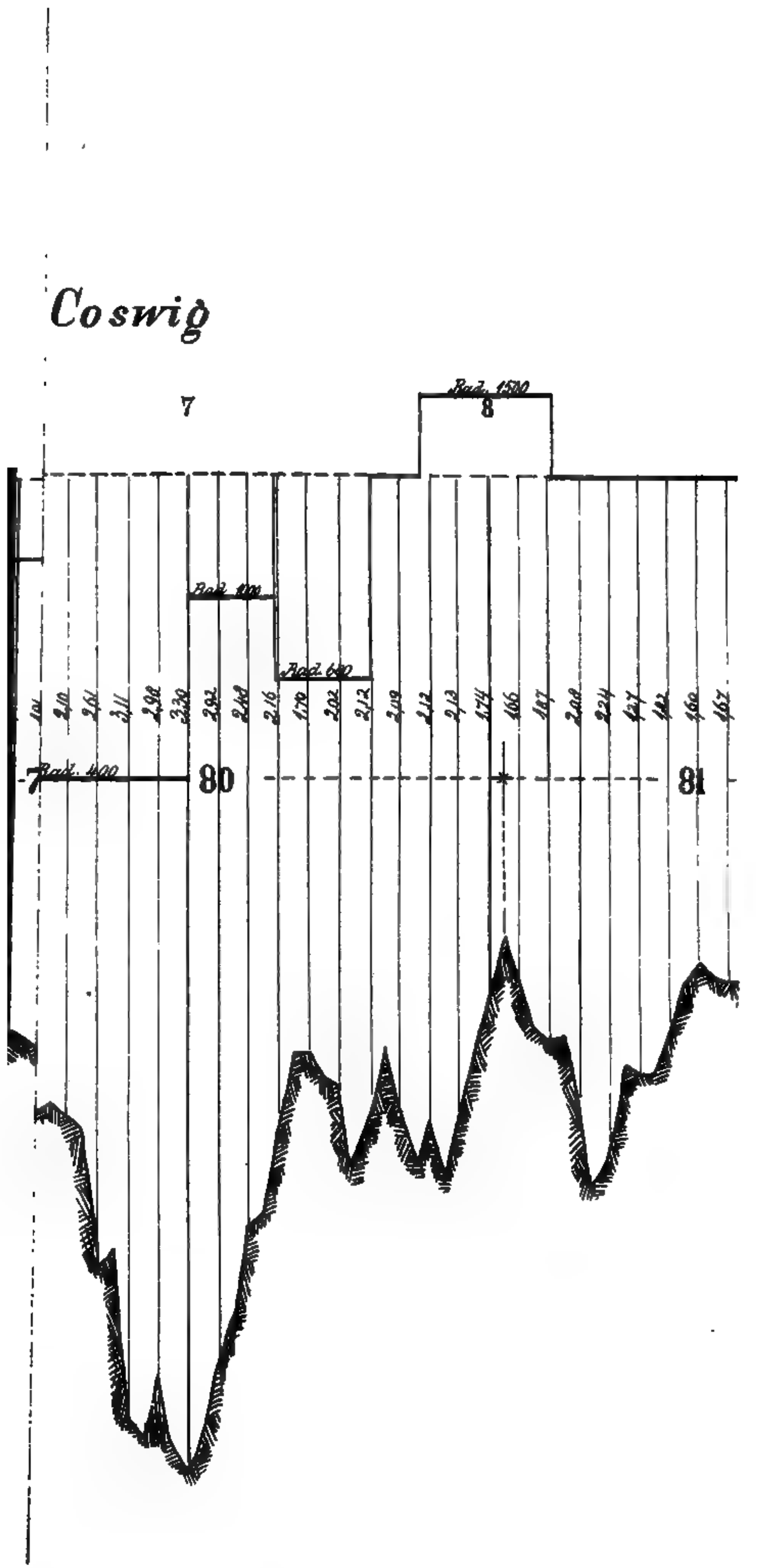




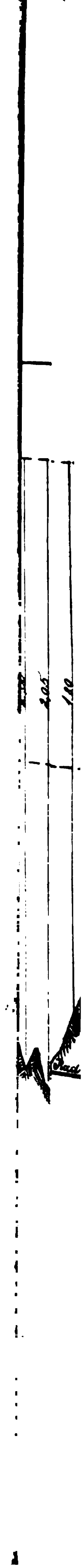
4

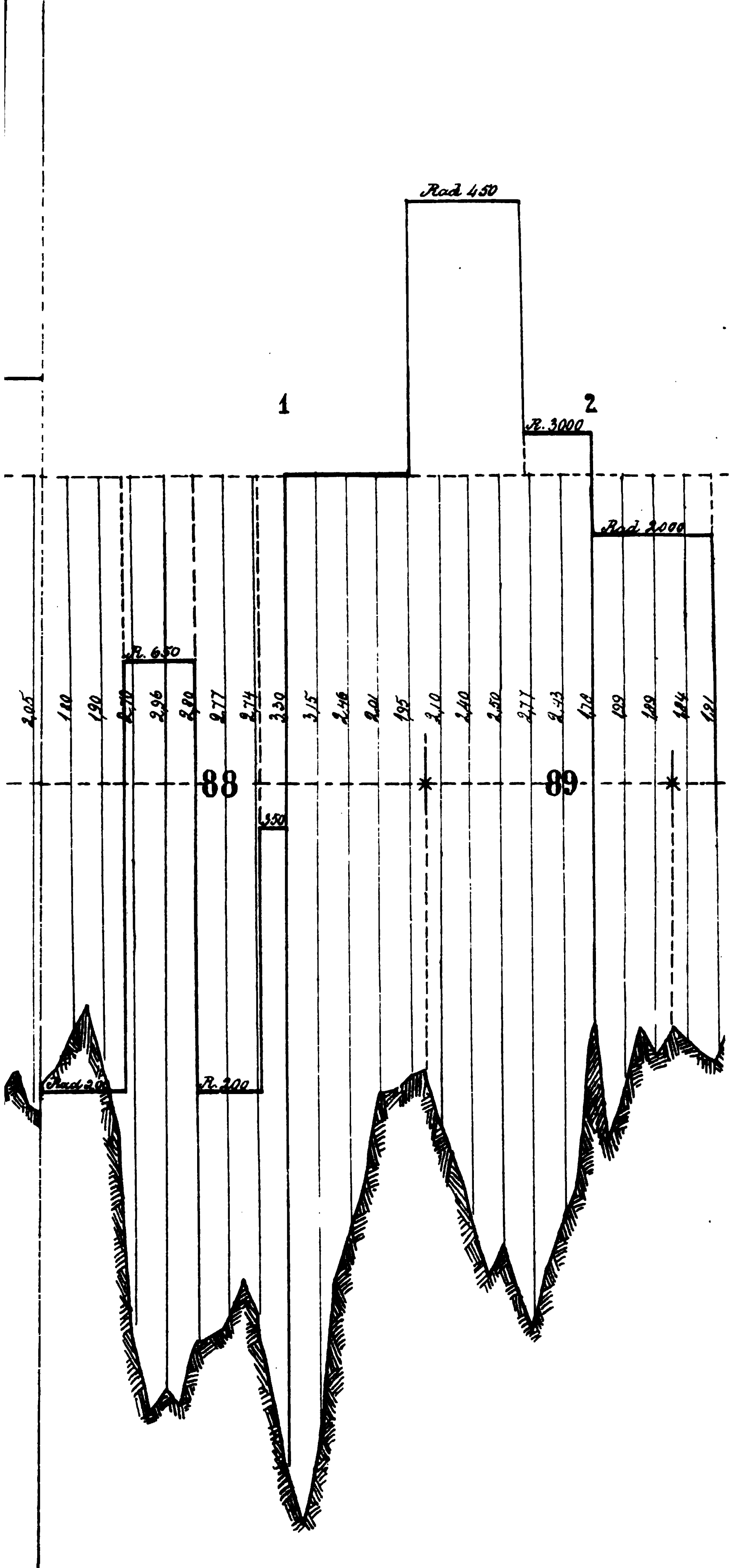
5





Coswig
7
Rad. 1500
8
Rad. 400
Rad. 600
1,91
2,10
2,61
3,11
2,98
3,30
2,92
2,48
2,16
1,70
2,02
2,12
2,09
2,12
2,13
1,74
1,66
1,87
2,08
2,24
1,27
1,82
1,60
1,67
Rad. 400
80
81





Rad 450
1
2
R. 3000
Rad 2000
R. 650
2,05
1,80
1,90
2,10
2,96
2,80
2,77
2,74
3,30
3,15
2,46
2,01
1,95
2,10
2,40
2,50
2,71
2,43
1,78
1,99
1,89
1,84
1,81
88
89
3,50
R. 200

21

VI[th] INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

6[th] QUESTION.

RELATION

between the form of river banks and the nature of the channel.

BY

P. MENGIN-LECREULX,
Inspecteur-Général à Paris,

AND

G. GUIARD,
Ingénieur en Chef des Ponts et Chaussées, à Paris.

THE HAGUE,
Printed by Belinfante B[the], late A. D. Schinkel,
PAVILJOENSGRACHT, 19.

1894.

CONTENTS.

PLATES.

VI^th International Inland Navigation Congress.

THE HAGUE, 1894.

Relation between the form of river banks and the nature of the channel.

BY

MENGIN—LECREULX,

Inspecteur Genéral à Paris.

AND

GUIARD,

Ingénieur en Chef des Ponts et Chaussées à Paris.

In these questions as in so many others the observation of facts is alone of any real value. It is therefore facts that the Congress especially demands.

We should have wished to furnish more, but the detailed study of a river requires much work, time and expense.

We give under the form of diagrams a comparative study of the widths, curves and depths for the maritime Garonne between Castets and the Ile de Laland, a distance of 51 km., and for the maritime Seine between Rouen and the sea, a distance of 104 km.

M. Guiard, Ingénieur en Chef, our successor at Rouen and our collaborator in this work, was good enough to draw up the diagrams and, as regards the Seine, elaborate an analysis and comprehensive discussion of the results. They will be found in § 7.

We also received certain information with respect to the maritime Loire, but the numerous wharves established on this river modify the *régime* of the bottom too much for it to be possible to gather any useful data from the study of the question.

With regard to the fresh-water portion of the Garonne two engineers have been good enough to prepare treatises.

One of them, M. Eschbach, has devoted himself to the study of a dis-

tance of 89 km., included between Agen and the boundary of the Department of the Garonne. Except in two places where the bottom is rocky, he has confirmed the relation between curves and depths and the law of digression. He states however that he has noted a great number of anomalies, which he has not pointed out in detail, but has confined himself to discussing the causes which are according to him foreign to the form of the mean bed. He proposes a system of low dikes.

M. Maillet has been occupied with a section of 6 km., where be has also confirmed the laws of relation and digression.

However important these two studies may be, it is desirable not to discuss them before we are able more effectually to substantiate the conclusions drawn from them. We will therefore devote to a future congress the examination of the points proposed.

The Congress has formulated a certain number of questions. We reply to its wish by treating certain of them succinctly and, without completely debarring ourselves from expressing our personal opinion, we have however endeavoured in general to avoid all purely theoretical discussion that is not founded on the facts presented by us.

§ 1. RELATION BETWEEN WIDTH AND DEPTH.

It has long been known that concavities give rise to hollows which are the more marked as the former are more characteristic. The exceptions or anomalies which are sometimes reported and from which argument has been drawn in disputes, are easily explained and do not in any way interfere with the general rule.

M. Fargue has pointed out this rule making it clear that the relation was closer than originally supposed and that all the variations of the curve along a concavity gave rise to corresponding variations in the depth.

This is clearly shown in the diagram of Plate I, which describes the widths, curves and depths of the Garonne for a distance of 51 Km. above Bordeaux between Castets and the Ile de Lalande.

This part which has been the object of the studies and labours of M. Fargue is affected by the tide which rises as far as Castets, but its action is hardly felt over more than half of this distance.

This diagram shows that the curve in the bottom nearly everywhere reproduces the curve in the banks with all its indentations. The few anomalies that may be remarked are easily explained, either by variations in width, especially below Langoiran, or by irregularities in the bed and local circumstances which the perusal of detailed plans alone can elucidate.

This study has been made and demonstrated by M. Fargue with the fullest detail. We have no occasion to return to this point, but it has appeared to us desirable in response to the question of the Congress, to

recapitulate the principal results under a form suitable for showing by a simple examination and a single glance the law of relation that it is required to establish.

With regard to the Seine, we refer to the detailed examination made by M. Guiard in § 7 and we confine ourselves here to a general view of the subject.

Unlike the Garonne where, at least between Castets and Langoiran, the succession in the variations in width is very regular, thus giving to the form of the bed and to the curves all their influence, on the Seine the incessant variations in width play an important part, a fact which is well set forth in the special diagram, Plate II, where the widths and depths are clearly indicated.

Moreover, resisting banks or banks not entirely unstable, rock, turf, pebbles and clay, all of which modify the results, are frequently illustrated at the bottom of the bed.

The influence of the curves is therefore more difficult to discern. These curves are represented with the depths in Plate III on the same scale as for the Garonne, and the diagram of widths, sections and discharges has been added.

We have said that the curve in the bottom generally depends on the curve of the width. Still, by looking closely, numerous differences will be observable and they can only be accounted for by the curves. By following the diagram point by point and by taking advantage of a knowledge of the bottom and resisting points there met with (see the discussion *infra*), it will be seen that there are hardly any indentations of the curve of the bottom, however capricious and unlooked for they may at first sight appear, that cannot be explained by the effect of the curves and variations in width acting sometimes together, at other times inversely.

This is quite natural, but it may not be amiss to demonstrate it, to show that the unstable bottom reflects all the circumstances of the bed, variations in width and curves, even those that we might have been tempted to consider insignificant. In fact to obtain the best possible result nothing must be neglected.

With regard to variations in one and the same curve the diagram gives little information, because unlike the Garonne where the curves, whether natural or artificial, are increasing or decreasing, on the Seine hardly any curves are met with that are not arcs of a circle, or nearly so.

If the variations in depth follow those of the curve, the proposition is not exact or at least is not always exact; that is to say that to a constant curve (arc of a circle) a constant depth of the same length does not correspond, but one or several maximum depths. The diagram of the Seine seems to estatlish this point, but we will return to it in dealing with beds formed of arcs of a circle.

If however after establishing a relation we seek to represent it in figures and formulae, we encounter great difficulties.

For the Garonne M. Fargue has established a formula but he specifies clearly that it only translates the local facts empirically and cannot be applied in other circumstances.

The width, the depth and the speed interfere to a degree that may be suspected but not established exactly. The details of the form, the nature of the bottom and the abundance of matter brought down interfere with these calculations; in fact in the present state of science there is no general formula that can be established and the most one can do is to search in every river or part of a river for an empirical relation.

Having said so much we will regard a few facts which may be considered as of information.

In the portion of the Garonne that has been studied the width varies from 150 to 200 m., the average speed when the water is at a normal height is about 0.80 m., the depth of water below low-water mark in the straight parts is between 1 and 1.5 m. For the hollows this depth varies from 2 to 11 m.; the latter figure corresponds to a curve 1 km. long with an altitude of 240 m., that is to say with a radius of about 400 m. or twice the width. A curve of the same length with an altitude of 100 m., corresponding to a radius of 1000 m. (five or six times the width), gives depths varying from 3.50 to 5 m. according to the width and the form of the bed.

On the Seine at Tancarville, the width is about 500 m., the speed, very variable according to high and low water and the time of high and low water, in springtides during the flood reaches a maximum of 3 m. and an average of 1.60 m. for three hours during the ebb, and a maximum of 2 m. and an average of 1.20 m. for seven hours.

The depth in the neighbouring shallows is 5.50 m. below the mean level. The concave curve is an arc of a circle having an altitude of 40 m. and a radius of 2500 m., or five times the width; its full extent is 4 km.; it causes a furrow the maximum depth of which is 13 m.; the average depth is hardly more than 8.50 m.

At Villequier, the radius of a curve of 1500 m. (also five times the width) causes a deepening of about 3 m., but at this point the water carried out by the tide, during spring tides, is already reduced by half.

§ 2. LAW OF DIGRESSION.

The law of digression which corresponds to a general law of nature is not disputed. It only remains to determine the effect of the digression.

In the part of the Garonne that he has studied, M. Fargue has shown, and it can be proved by the diagram, that the amount of the digression varies in general from $1^1/_2$ to 2 times the width and he thinks that the latter ratio may be admitted.

The same ratio, viz. twice the width was found from the experiments made in 1875 at Bordeaux on an artificial river 1.5 m. wide for the study of the rational forms of river-beds. This study has given very interesting and convincing results which M. FARGUE has also elsewhere given some account of (Paris Congress 1892; Annales des Ponts et Chaussées, March 1894).

On the Seine, as may be seen in § 7, the digressions vary from 400 to 1200 m., the width varying from 200 to 500 m. The average ratio therefore is still 2 to 1, but as a matter of fact this ratio on the Seine is far from being constant. It probably varies with the speed of the current and certainly with the circumstances of the form of the bed. A form of bed with a sharp bend might be conceived where the digression would be insignificant. Beds of rational form by the good management of concavities and the judicious determination of their development seems to us to have for result the prolongation down stream of the action of the concavities.

However that may be, a knowledge of the law of digression is useful for the determination of the dimensions of curves and the respective position of tangents on either bank; from this point of view and under the usual conditions of speed, the ratio of 2 to 1 between the digression and the width appears at present to be admitted.

§ 3. INFLUENCE OF THE DISCHARGE AND OF THE WIDTH UPON THE DEPTH IN REGULAR CURVES.

This question is very simple or very complex according as one would understand it.

Every reduction of width with an equal or regular discharge, every increase in discharge with an equal width, increases the influence of the curves.

But all engineers know that this mode of action has limits which it is most important not to go beyond.

This however is independent of the question of the form of beds and we cannot here go into it.

The question of greatest importance is the regulation of the width which the doctrine of sinuous rational forms of beds in no way pretends to reduce. This doctrine only attempts to furnish for regular widths and discharges a deeper and more stable channel, or what cames to the same thing, secure the necessary results of navigation with greater average widths and more moderate speed. The latter is often a most important factor, especially in tidal rivers.

On the Seine, commencing at Caudebec, a system of increasing the width down stream has been adopted which has proved too feeble in consequence of the strength of the tide. The inclines and the speed have

increased, the bed has dug itself out, but not sufficiently, and the speed has remained excessive. The result has been grave inconveniences which have to be contended with to-day.

In spite of this general excess of speed and insufficient width, it is proved, and the subjoined diagram shows it, that at certain points, as for instance at St. Léonard, a local increase in width causes a shoal, although upon this same shoal the speed remains great and the bottom is unstable.

This very important fact shows that as regards the nature of the bottom it is not only the absolute speed and width that must be considered, but their continuity. If the bed is straight the continuity will be absolute, if it is sinuous there will still be continuity, but of another nature, the width being for excellent reasons, often enlarged upon, necessarily greater at the apex of curves than in the places where the direction changes, but varying from one to the other in imperceptible degrees in such a manner that curves, widths and depths form similar diagrams.

At St. Léonard the increase in width contrary to the general principle is at the point where the direction changes; this will be changed and the width of the stream will be increased parallel with the apices of the curves of Tancarville and Aizier.

§ 4. INFLUENCE OF A BED FORMED BY STRAIGHT LINES AND ARCS OF A CIRCLE COMPARED WITH THE INFLUENCE OF A BED CONSTRUCTED ACCORDING TO THE SYSTEM OF M. FARGUE.

The rules pointed out by M. Fargue are legion. A great number of them, and these not the least important, are compatible with a bed composed of straight lines and the arcs of a circle, as for instance the determination of the development of the curves, determination of the angle of the tangents or successive straight lines, distribution of differences in width, position of points of tangence. If these conditions are fulfilled, the difference will then only bear upon the principle of the continuity of curves.

The rupture of continuity at the point of tangence will give place to a corresponding discontinuity of more or less disportance in the relief of the *thalweg*, according as the ratio between the curve and the speed shall be greater. The bend at Tancarville is an example — it is produced in this case above the curve — and has given considerable trouble as may be seen from the diagram, a trouble which is caused moreover by the irregularities of width, resulting from the irregular crumbling away of the convex bank which is not diked and is exposed to swift flowing water.

What occurs between the points of tangence along the arcs of the circle? Studies made on the Garonne (Annales des Ponts et Chaussées,

1868), the experiments made in 1875 at Bordeaux mentioned above, the examination of what has occurred at the bend of Tancarville on the Seine, seem to establish the fact that along a circular curve we find not a constant depth corresponding to the constant curve, but as we have said above one and sometimes several maximum depths and variable positions according to the variations of speed. The result of this is that if they are frequent they cause incessant alteration in the bottom and the dislodging of matter to the detriment of the channel generally.

This is a most important question which might with advantage be elucidated more by a more numerous collection of facts.

It is at present in our opinion certain that arcs of a circle give less satisfactory results, especially if the speed is great and variable, circumstances met with particularly in maritime rivers when the tide is strong.

In a river of this nature if abandoning the rectilinear form of bed we introduce curves, the continuity of these curves becomes extremely important.

It is our opinion however that, especially in a quiet and regular river with a bed in the form of arcs of a circle already in existence and well arranged in all other respects, we shall be able to come to a proper result; but we think that for a new bed, it is always necessary to have recourse to graduated curves.

§ 5. INFLUENCE OF HIGH AND LOW WATERS ON THE DEPTH OF THE CHANNEL IN BENDS.

High waters increase the depth, the speed and the discharge of solid matter.

In the first two instances the deep places should become deeper; but in certain badly combined forms of beds it may happen that the result becomes hidden by the amount of solid matter brought down.

A very important consideration is connected with this point. The form of the line traced by the most effective part of the current, which determines the *thalweg*, depends on the. form of the banks, but also on the conditions of heigh of water and the speed with which this line necessarily changes. In. the form of beds recommended it is proposed by the continuity of curves and their suitable development to reduce to a minimum the variation of the line in question. This is connected with what we have already said above with reference to circular arcs. It is a point to be studied.

We may mention however that the increase in width at the apex of the curve combined with an accentuation suitable to concave and convex curves has, among other ends in view, the effect of creating spaces where the action is less strong. These are sufficiently important and defi-

nitely formed for the matter brought down by the floods and stranded when the water is low to be able here to deposit itself and finally continue down stream from one concavity to another without stopping in the channel.

This theory has been developed by M. Fargue and is of great service in making comparisons between straight and curved beds.

We mention it without pressing the question, not being able to furnish any precise facts. It would be interesting and useful to verify this theory, which might perhaps be done by taking soundings at suitable seasons very close together, or even by cubic measurement ahead of the convexities. Unfortunately these are minute and tedious operations which one has not often the leisure to undertake.

§ 6. MAXIMUM OF SINUOSITY.

The Garonne and the Seine are very tortuous.

The diagram shows that in the best portions of the maritime Garonne above Bordeaux very accentuated curves are found, which describe angles of as much as 120° with the radius of the curves, the ratio between which and the width is reduced to 2 at the apex and 4 for the mean curve. The width is about 200 m.; the mean annual discharge per metre in width per second is 3 or 4 cub.m.

On the Seine above Caudebec, under similar conditions of width and discharge, curves of the same nature are found, which, not counting the irregularities of width and bed, do not appear to offer any serious inconveniences and would give good results if they were well managed.

Below Caudebec the speed increases rapidly and the situation changes.

At Tancarville, for a width of 500 m. with sudden discharges which, varying incessantly in the most spread out parts of the river, are 6 or 8 cub.m. per metre in width per second at mid-tide and in spring tides and reach a maximum of 10 cub.m. during the ebb-tide and 18 cub.m. during the flood, an arc of a circle of about 90° with a radius of 2500 m., or five times the width, occasions considerable trouble and thus constitutes an excessive sinuosity.

These facts are not sufficiently numerous to enable us to form any fixed or general conclusions.

We shall only observe that the case of Tancarville is absolutely exceptional and abnormal; it is caused by bad management of widths. In general the conditions usually met with are more like those of the Garonne.

By adopting 80° or 100° as the angle of sinuosity good practical conditions will be obtained.

The facts relating to Tancarville also show that in a tidal river operations must be regulated by spring tides and not by neap or average tides.

This raises the general question of the effect of sinuosities in tidal

rivers. Many engineers declare that there is good reason for suppressing them, because they interfere with the rising tide and the hydraulic force of the stream.

With regard to the filling up of the bed there is no doubt; still we must also consider the good *régime* of the channel of navigation and the action of the ebb-tide. If it is admitted, as we think it should be, that in these latter circumstances straight forms of beds, or those that are too little or too irregularly sinuous, present inconveniences, we shall find we have two contrary principles to reconcile. This may be done by softening down the sinuosities and regulating them as well as possible by means of graduated curves and a suitable regulation of the width by means of which, as the example of the Garonne proves, we may considerably reduce, even during the flood, the loss of power and guard against the filling up of the channel. At Tancarville, although the exaggeration of the curve is certainly an obstacle, the insufficient width is nevertheless the principal factor.

This therefore remains an open question; but however we may wish to do away with the sinuosities, it is not always easily done, and if they are preserved they still require the best possible management.

From this point of view at least the study of rational sinuosities is important and essential for tidal rivers as for others.

One of the questions set forth by the Congress has reference to the practical rules to be adopted in choosing the form of bed and constituting the summer bed in both tidal and non-tidal rivers; the magnitude of it is so great that it would be imprudent for us to touch upon it.

§ 7. ANALYSIS OF THE DIAGRAMS OF THE MARITIME SEINE.

We have taken as a level of comparison the average level of the ebb-tide, or the level obtained by dividing the total duration of the ebb by the area of a curve of which the abscissa represents the time and the ordinate the corresponding height of water, i.e. if $T =$ duration of ebbing tide, h = the height at each moment, and H = the height of water corresponding to the average height of the ebbing-tide:

$$H = \int_{o}^{T} \frac{hdt}{T}.$$

We have brought down to this level all the diagrams connected with the present study.

Plate III gives drawings of

1. Sections;
2. Widths;
3. Discharges;
4. Concave curves;

(these latter being connected in the same drawings as they are on one bank or the other).

5. Same depths reduced to the level of the marine charts;

6. Maximum depth of water with regard to the level of the ebbing-tide.

We shall point out directly that the soil in many parts of the Seine being incapable of being washed away, there are ledges which form dams, for which all theories founded upon the mobility of the bed cease to be applicable.

Besides these ledges the Seine throughout its length presents great varieties of width, a fact which forms a complication with regard to the laws observed on a part of the Garonne where the width is sensibly constant. It was therefore very interesting to nullify the influence due to the variations of curvature and that due to the variations in width.

It is in this sense that we have prepared the present study.

We should also remark that the importance of the volume of water being equal to $^{75}/_{100}$ of the volume of water discharged and on the other hand the duration of the flood being equal to $^{5}/_{7}$ of the ebb, it follows that the bed of the Seine may be considered as giving passage at each tide, at least in the lower portion, to two strong currents of equal force running in opposite directions.

Under these conditions the effect of the curves being given, the law of digression should be felt in both directions to a greater or less degree, according to the points considered and also according to the degree of inconvenience caused by the curves during the ebb or flow of the tide.

We will step by step follow the Seine from Tancarville as far as Rouen; we will not deal with the lower portion of the river, for the variations in the channels of the estuary have an influence foreign to the study with which we are at present occupied.

We give in Plate II a special diagram in which we have only indicated the depths at the average level of the ebb-tide and the width.

This comparison brings out in a most striking manner the relation between the widths and depths observed.

It seems that in the main the two diagrams are in every respect parallel.

We will keep back this important point and pass on to Plate III.

The influence of the variations in width between kilometres 331 and 334 is corrected on the drawing of the depths by the influence of the curve, which greatly accentuates the first indentation 1000 m. below the apex of the curve and which on the contrary skirts the shoal corresponding to the width 1000 m above this apex.

At the same time the influence of the change in direction at kilometre 332.5 is sensibly felt, there being a digression of at least 500 m. down stream.

The action up stream is not felt in consequence of the existence of

sunken banks to which are due the deepening of kilometres 332 and 333; there is here a local action which need not enter into our study.

The influence of the creek of St. Léonard at kilometre 330 and the consequent shrinking of the bed is very striking.

It is the same with the increase in width towards kilometre 327.

The effect of the curve of Vieux Port is shown by a digression of about 500 m. an up stream and 700 m. down stream.

With regard to the deepening of kilometres 323 and 324, it is due to the presence of the bank of Les Hagues which forms a regular bar, against which the flood tide exhausts itself in undermining it.

The effect of the next curve occasions digressions of 600 m. up stream and 900 m. down stream.

The curve between kilometres 315 and 316 has but slight effect down stream, but is very appreciable up stream, causing a digression of 250 metres; this would go to establish a principle that a short and abrupt curve exercises a more marked action on the flood than the ebb.

The three indentations in the width at Villequier appear in the depths, attenuated and modified as regards their position by kilometre 313 to 314. It seems that the digressions due to the curve are 400 m. down stream and 800 m. up stream.

The effect of the curve of kilometre 311 is felt 700 m. up stream; the effect down stream manifests itself by causing the incline of the *thalweg* to be steeper than it would have been if the variation in the width alone had been taken into account.

The influence of the change in direction between kilometres 310 and 311 causes a mound up stream which the width no longer justifies and a digression of 400 m.

In the same way between kilometres 309 and 308, the combined effect of the curve and the variations in width is very sensible and corresponds to a digression of 400 m. up stream and 600 m. down stream.

We will not stop at the holes in kilometres 304 and 305 m., 300 m. corresponding to sunken dams. The effect of the curve of kilometre 305 and 306 is felt down stream by a digression of about 800 m.

Further on we find the influence of the widening at Le Malacquis very clearly corrected 500 or 600 m. down stream by the curve of kilometre 302.

The great depth of bottom between kilometres 300 and 301 depends upon a submarine bank; it is independent of the curve between the two kilometres; the effect of the latter is felt with a digression of 700 m. down stream.

The curves between kilometres 300 and 295 combined with the variations in width give almost exactly the same depths and shallows as result from M. Fargue's theory with a digression of 700 m. down stream.

The great stretch of deep water met with at kilometre 296 depends on the existence of a submarine cape; it has nothing to do with the curve or the width at low-tide level.

The influence of the hole of Les Hagues coinciding with a straight line determines a shallow, after which the *thalweg* again obeys the law of variations in width with the corrections due to curves.

The minimum depth at kilometre 291 corresponds to a minimum curve at a spot where the width is also minimum and with a digression down stream of about 500 m.

In the same way the effect of the curves of kilometres 285 and 283 is very plainly felt 400 m. down stream by a mound, due to the excess of width. (See Plate II.)

Between kilometres 283 and 274 the same effect is produced with digressions of 300 or 400 m. down stream.

We meet with the same results at the bank of Bardouville, although much enfeebled by the slight mobility of the bottom and altered by the dredging that has latterly been effected.

Starting from kilometre 265 we meet with a great depth at Caumont due at once to the shrinking and to a considerable bend with digressions which appear to be 800 m. up stream and 400 m. down stream.

We next have depths corresponding almost exactly with the variations in width.

The influence of the curve is also very clearly shown between kilometres 258 and 254. But in this region as far as Rouen the presence of numerous islands through which channels have been dug no longer permits us to draw any conclusions.

The above analysis shows that the variations of depth on the Seine clearly depend on the variations in width combined with curves.

Wherever there are only variations in width, the various depths of the channel appear to follow them without any appreciable digression. Wherever the variations in width are relatively continuous, the depth follows the influence of the curve and the form of the bed.

It would even seem that in ground only slightly susceptible to the action of the current the above effects continue to occur, although their absolute intensity is reduced.

Wherever we have together an increase in width and a reduction in the curves we are certain to have shallows.

Although it is a very delicate matter to fix the digressions, as we have done above, and may in certain cases give rise to dispute, it is remarkable that the digressions up stream are met with between Tancarville and Le Trait, where they disappear.

It is precisely at Le Trait that the bore ceases to be felt.

The most marked digressions up stream are at Tancarville, near Villequier, that is to say in those places where the width is least.

We meet also with another exceptional digression up stream; it corresponds to the abnormal shrinking at Caumont.

If we compare these results with the indications drawn from the curves and discharges, we see that the volume introduced by the flood-tide diminishes very rapidly between Tancarville and Le Trait. From there as far as Caumont it remains almost constant, diminishing once more very rapidly up to Rouen.

All contractions and sinuosities interfere with the introduction of the tide and, according to their dimensions, more or less affect the hydraulic power of the river.

SUMMARY AND CONCLUSIONS.

A. *The relation between curves and the variations in depth is demonstrated by the Garonne and maritime Seine. On the Garonne where the variations in width are relatively very regular and the curves gradual, the variations in depth are identical with the curves. On the Seine where the variations on the contrary are very irregular, the two actions combine and, by comparing the diagrams, the influence of these two causes respectively may be observed point by point.*

B. *The action of the curves increases with the width, the depth and the speed, that is to say the discharge, and also depends upon their circumstances — the nature of the bed, the naturé of the bottom etc. — all of them in proportions which cannot be formulated in a general manner.*

It is natural to express the influence which is probably proportional to the width by calculating the curves by the ratio between the radius of the curve and this width. On the Garonne, with an average discharge per metre in width per second of 3 or 4 m., the ratio between the radius of the curve and the width may, without inconvenience to the channel, or apparently with advantage, be 4 for the mean curve and 2 for the apex. The Seine above Caudebec presents similar conditions.

Below Caudebec, at Tancarville, the ratio of 5 for a curve (the arc of a circle) is manifestly excessive and provokes serious troubles for the average discharges per metre in width, since these latter are nearly double, and in spring tides three or even four times, the flood by reason of the height of the tides and the insufficient width.

C. *The law of digression, which on tidal rivers acts in both directions, is general. The digression, which varies according to the conditions of the form of the bed and the discharge in proportions not yet determined, is especially caused by the width.*

For practical purposes in the management of the forms of beds the ratio of 2 *between the digression and the width may be adopted.*

D. *The regulation of the width is above all the most important consideration, not even the doctrine of the rational sinuous forms of beds has been able to lessen its influence. The latter only attempts to obtain better results where the variations are regular and presumed to be suitable.*

The comparative merits of straight and sinuous forms of beds constitutes a question which still remains open; but in every case, as these sinuosities are most often inevitable, it is still necessary to study how they should be managed in order that they may be as useful, or as little hurtful, as possible, which practically comes to the same thing.

E. *The same observation applies to sinuosities in tidal rivers.*

They always to a greater or less degree according to their importance admit of a loss of effective force, which interferes with the introduction of the flood and the hydraulic power of the river.

Besides M. FARGUE *many engineers advise the suppression of them. This controvertible and delicate question remains open, but still generally speaking it will be necessary if not to introduce sinuosities at any rate to reduce them. It is therefore necessary on tidal rivers as on others still further to study their management.*

F. *The forms of beds formed of straight lines connected by arcs of a circle, if they are well managed as regards their curves, their development, the position of the points of tangence, successive variations in width, may give satisfactory results; but the substitution of arcs of a circle for graduated curves, which only corresponds to a simplification without practical interest, can nevertheless only present inconveniences. To appreciate this it might be useful to take observations respecting the nature of the depth along the arcs, especially with regard to the variations in discharge.*

G. *All variations in discharge, high and low waters in ordinary rivers, spring and neap tides in tidal rivers, complicate the management which is the more easy according as it is most regular. The forms of beds recommended by* M. FARGUE *are culculated to reduce to a minimum the variations in the line where the action of the current is strongest, which determines the* thalweg, *and to create in the convexities a system of alternate curves, where matter is deposited after successive floods and droughts. These points present a capital importance, but require verification and doubtless may still be the subject of much dispute.*

H. *The use of synoptic diagrams, which are intended to make clear all the elements which characterise a river and have a mutual influence, is effective and even essential not only for the advancement of science, but also for carrying out improvements independently of any theory and for controlling results.*

Translated by FRANCIS A. OLIVER.

Inscriptions des Planches.

PLANCHE I.

Diagramme des largeurs.

Diagramme des courbures concaves des rives.

On a porté en ordonées au-dessous de l'axe des abscisses, les valeurs de . . . . .

Diagramme des profondeurs d'eau maxima au-dessous des zéros des échelles.

Passes et lieux dits:

PLANCHE II.

Diagramme des largeurs au niveau moyen de jusant.

Axe de la rivière développée.

Lieu géométrique des profondeurs d'eau maxima au-dessous du niveau moyen de jusant.

Digue basse.

Rescindement projeté de la convexité.

Digue détruite.

Trou.

Sable fin, fond mobile.

Sable vaseux.

Fonds non mobile, quelques roches.

Sable vaseux mélangé de quelques galets, assez mobile.

Gravier et galets, quelques roches.

Cailloux, gravier et sable.

Vase et argile très dure.

Cailloux et vase très dure.

Tourbe.

Mengoin-Lecreulx & Guiard.

Inschriften der Zeichnungen.

BLATT I.

Breitendiagramme.

Diagramm der Krümmungen der concaven Ufer.

Man hat die Werthe von . . . . . in Ordinaten unter der Abscissenachse eingetragen.

Diagramm der Maximalwassertiefen unter den Nullpunkten der Pegel.

„Pässe" und Stellen, genannt:

BLATT II.

Breitendiagramm bei mittlerem Ebbe-Wasserstande.

Achse des entwickelten Flusses.

Geometrischer Ort der Maximalwassertiefen unter dem mittleren Ebbe-Wasserspiegel.

Niedriger Deich.

Geplante Abänderung der convexen Form.

Zerstörter Damm.

Loch.

Feiner Sand, beweglicher Boden.

Schlammiger Sand.

Nicht beweglicher Boden, einige Felsköpfe.

Ziemlich beweglicher schlammiger Sandboden, mit etwas Flusskiesel vermischt.

Grand und Flusskiesel, einige Felsköpfe.

Kieselsteine, Grand und Sand.

Schlamm und sehr harter Thon.

Kieselsteine und sehr zäher Schlamm.

Torf.

Description of the Plates.

PLATE I.

Diagram of widths.

Diagram of concave curves of the banks.

The values . . . . . have been represented by ordinates below the axis of the abscissae.

Diagram showing maximum depths of water below the zero marks of the scales.

Passages and places called:

PLATE II.

Diagram of width at the mean level of the ebb.

Tracing of the course of the river.

Locus of maximum depths at the mean level of the ebb.

Low dike.

Projected modification of the convexity.

Ruined dike.

Hole.

Fine sand, unstable bottom.

Slimy sand.

Constant bottom, a few rocks.

Slimy sand mixed with pebbles, rather unstable.

Gravel and pebbles, some rocks.

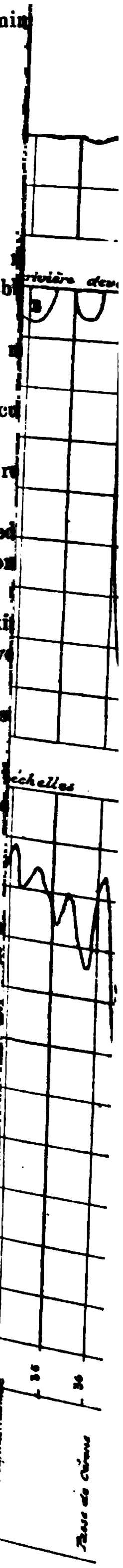
Stones, gravel and sand.

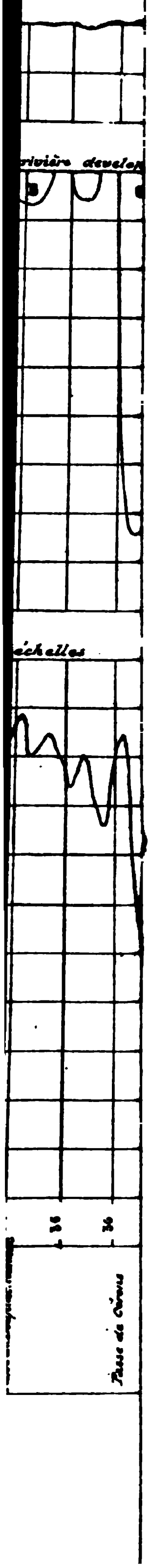
Slime and very hard clay.

Stones and tenacious mud.

Turf.

Sable vaseux mélangé de coquillages minuscules.	Schlammiger Sand mit ganz kleinen Muscheln vermischt.	Slimy sand mixed with mi shells.
Argile compacte et argile sableuse.	Massiger Thon und mit Sand vermengter Thon.	Hard clay and sandy clay.
Argile, sable et marne.	Thon, Sand und Mergel.	Clay, sand and marl.
Sable et gravier.	Sand und Grand.	Sand and gravel.
PLANCHE III.	**BLATT III.**	**PLATE III.**
Diagramme des largeurs de la rivière au niveau moyen de jusant.	Breitendiagramm des Flusses bei mittlerem Ebbe-Wasserstande.	Diagram showing width of at the mean level of the eb
Diagramme des sections au niveau moyen de jusant.	Querschnittsdiagramm bei mittlerem Ebbe-Wasserstande.	Diagram of sections at the level of the ebb.
Diagramme des courbures concaves des rives des fleuves.	Diagramm der concaven Krümmungen der Stromufer.	Diagram of the concave c of river-banks.
On a porté en ordonnée la valeur de	Man hat den Werth von . . . . . als Ordinate eingetragen.	The value . . . . has been r sented by the ordinate.
Sur ce diagramme est indiqué la valeur de la courbure kilométrique.	Auf diesem Diagramme ist der Werth der kilometrischen Krümmung angegeben.	On this diagram is indicate value of the curve a kilo in length.
Diagramme des profondeurs d'eau maxima au dessous du niveau moyen de jusant.	Diagramm der Maximal-Wassertiefen unter mittlerem Ebbe-Wasserspiegel.	Diagram showing the maxi depths below the mean lev the ebb.
Diagramme des débits totaux de jusant.	Diagramm der Gesammt-Wasserabfuhr bei Ebbe.	Diagram showing the total di ges at low water.
Diagramme des cubes introduits en amont des diverses stations de la Seine.	Diagramm der oberhalb der verschiedenen Seinestationen eingeführten Wasserinhalte.	Diagram showing amount of received above certain plac the Seine.
Rive droite.	Rechtes Ufer.	Right bank.
„ gauche.	Linkes „	Left „
Le développement de l'axe de la rivière est représenté à l'échelle de	Die Entwicklung der Stromachse ist im Maasstabe von . . . . wiedergegeben.	The diagram showing the fo the river-bed is represente scale . . . .
Zéros des diagrammes des largeurs, sections, courbures et profondeurs.	Nullpunkte der Breiten-, Querschnitts, Krümmungs- und Tiefen-Diagramme.	Zero lines of the diagrams s the widths, sections, curv depths.
Zéro des diagrammes des débits.	Nullpunkte der Wasserabfuhr-Diagramme.	Zero lines of the diagrams ing the discharges.
Le niveau moyen de jusant audessus du zéro des cartes marines au Hâvre est	Der mittlere Ebbe-Wasserspiegel über Null auf den Marinekarten in Havre liegt	The mean level of the ebb the zero mark of the naval at Havre is . . . .
(Pour les autres inscriptions, voir les traductions Pl. II.)	(Die anderen Ausdrücke, siehe Uebersetzungen zu Blatt II.)	(For other references see the lations under plate II.)
Inscriptions souvent répétées.	Häufig vorkommende Inschriften.	Words frequently repeated.
Digue.	Deich, Damm.	Dike.
Echelle.	Maasstab.	Scale.
Légende.	Zeichenerklärung.	References.
Pont.	Brücke.	Bridge.




échelles


243

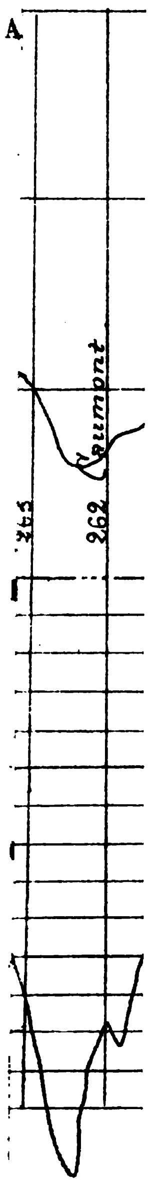
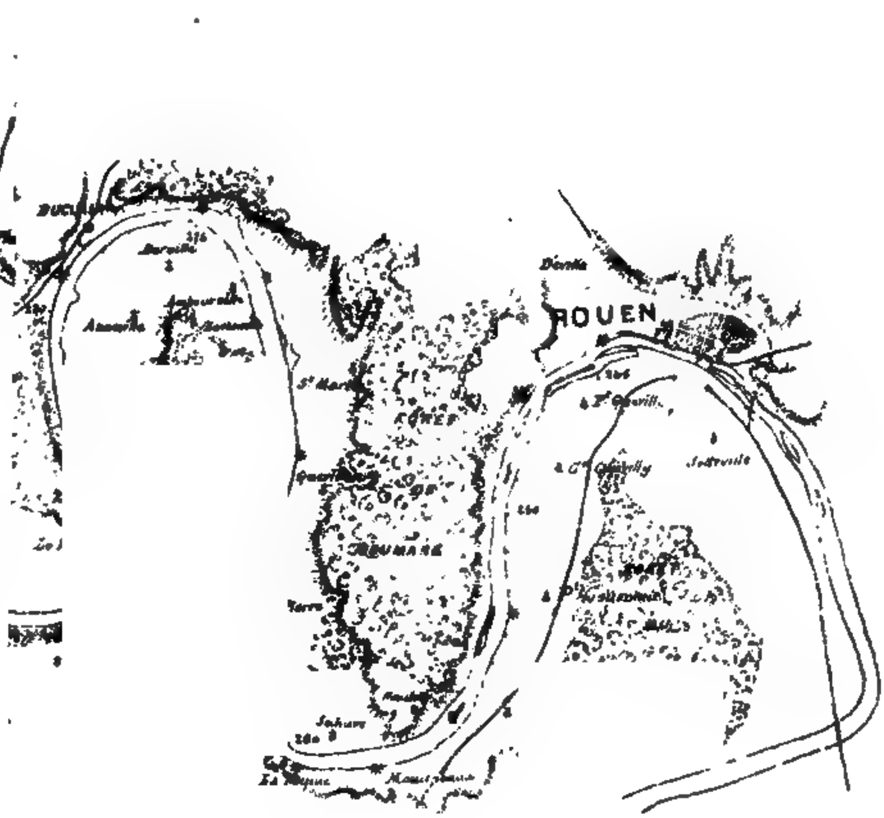


Planche No. IV.



STEENDRUKKERIJ v/h. AMAND, Amst.

22-27
according to French set

VI^th INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

6th QUESTION.

RELATIONS BETWEEN THE configuration of rivers and the depths of their channels

BY

R. J. CASTENDIJK,
Ingénieur de 1ère classe du Waterstaat, à Nimègue,

H. DOYER,
Ingénieur de 3ème classe du Waterstaat, à Zutphen,

J. G. ERMERINS,
Ingénieur de 2ème classe du Waterstaat, à Utrecht,

R. P. J. TUTEIN NOLTHENIUS,
Ingénieur de 2ème classe du Waterstaat, à Bois-le-Duc,

C. B. SCHUURMAN,
Ingénieur de 1ère classe du Waterstaat, à Dordrecht,

D. J. STEIJN PARVÉ,
Ingénieur de 2ème classe du Waterstaat, à Rotterdam.

THE HAGUE,
Printed by Belinfante Bths, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

VIth International Inland Navigation Congress.

THE HAGUE, 1894.

Relation between the form of river-banks and the depth of the channel or thalweg.

BY

R. J. CASTENDIJK,

Ingénieur de 1re classe du Waterstaat à Nimègue.

For the investigation of the relation forming the subject of this question a longitudinal sketch of the Wahal has been drawn up and will be found subjoined to the present treatise.

For the necessary data concerning the capacity, levels etc. of this river, as well as its normalisation, I refer to the information given on this subject in the memorandum composed by M. VAN DER SLEYDEN in consort with myself upon the seventh question.

With regard to the works executed since 1888, the following remarks may be made.

The interests of navigation required a greater continuous depth of channel than that afforded by the works in existence before that year. It resulted from a calculation that, by a contraction of the bed of the river which in summer is 360 m. wide in the straight parts of its course and 310 m. in the curves, an average depth of 3 m. might be met with, taking as a standard a level of about 1.25 m. below the mean low-water mark during the years 1871—80; at this low level it is calculated that the discharge will be 870 cub. m. per second. In the straight parts of the course a depth of channel about equal to the average depth might be counted on. Provisionally however we might be satisfied with a depth of 2.70 m.

In the project for the improvement of the Wahal the normal width was as far as possible maintained at the apex of the curves.

The methodical widening and contracting of the normal bed and a regular transition of the straight portions to maximum curves in the

sinuosities were obtained by joining the straight banks to increasing and decreasing curves.

For this purpose lemniscates, recommended by M. FARGUE, were employed, the general equation in polar coordinates being:

$$r = A \sqrt[n-1]{\sin(n-1)\,\Theta}$$

where n and A are constants which may be chosen in such a manner as to obtain the most favourable line in any given case.

The lines chosen should depart as little as possible from the situation existing in 1889 and should not cause the destruction of existing works.

In drawing up the project it was supposed that arcs of a circle of a radius of 3000 m. might without difficulty be allowed. Also for the almost straight portion of the river from Nimègue to Tiel (Kilometres 26--56) such arcs were almost exclusively used.

The lemniscates which we have just referred to were applied to arcs of less radius.

(See the article on this subject by M. DOYER in the „Tijdschrift van het Koninkl. Instituut van Ingenieurs", 1891—1892, pp. 1—13).

On the lower part of the river, where the ebb and flow of the tide is felt, commencing below Hurwenen near kilometre 70, the normal width down stream increases regularly in the straight portions from 310 to 400 m. and in the curves to 426 m.

The contraction of the bed in time of drought was effected by groins which slant into the river at an incline of 4 in 1.

Where the existing works were not situated too far from one another they were lengthened to meet the new normal lines at right angles.

Where the intermediate distances were too great new works were built between those already existing.

Outside the fascines dredging had been carried on on a large scale to deepen the shallow places where it was desired to direct the channel.

The object of this dredging was:

1°. To hasten the formation of a continuous channel.

2°. To prevent objectionable movement of sand in places below which works were in the course of construction;

3°. To widen the transverse section where it was inclined to contract owing to the groins;

4°. To remove the influx of sand from the German Rhine.

The project which was formed in 1889 on this basis, the cost of which was estimated at fl. 2500000 to be distributed over four years, included the prolongation of 267 existing groins, with a total length 9425 m., the construction of 49 new groins, of a total length of 3479 m. and the

removal by means of dredges of 3458000 cub.m. of sand from the bed of the river.

The necessary funds were voted by the law of October 28th 1889.

The work was carried out in the years 1889, 1890, 1891 and 1892. The cost amounted to more than the fl. 2500000 at which it was estimated.

The works constructed were:

95 new groins, in length	6385 m.
2 dikes along the banks	676 „
lengthening of 305 groins of a total length of .	10139 „
Total . . .	17200 m.
Total of matter dredged	6849000 cub.m.

This work has in general realised the expectations formed of it, especially as regards the requisite depth, 2.70 m., which has been obtained almost throughout.

In the lower part of the river, near Loevestein, where this depth was not quite reached in 1893, we can hardly expect a constant condition of the bed as long as the waters of the Meuse have access to it. This access will be cut off when the mouth of the latter river is changed. The subjoined chart represents the condition of the part of the river near Heerewaarden in 1894 after the completion of the works mentioned above and of the same part in 1861 when no normalisation had as yet been effected.

On both of them have been drawn lines showing a depth of 3 m. below low-water mark, which is 3 m. above N. A. P. (1) at St. Andries, equal to 1.40 m. below the mean low-water mark of 1871—80 (4.40 m. above N. A. P. at this point).

The subjoined longitudinal section represents the condition on the upper Rhine and upper Wahal at the commencement of 1894.

Besides the average depth of the normal bed in each transverse section, it indicates both the greatest and least depth of the channel, calculated over a width of 150 m. for the upper Rhine (kilometres 0—10) and of 100 m. for the Wahal.

Above the longitudinal section properly so called the width of the river has been represented, measurements having been taken between the heads of the groins where the normalisation works exist and at the height of mean low-water where there are none.

Below the longitudinal section is found the curve formed by the normal banks. As the plane surface of the sketch is the vertical projection of a cylinder, the position of the bed being normal and indicating the direction, and everything is projected upon it, the curves have under-

(1) New Standard of Amsterdam.

gone some modification in their form. However this presents no inconvenience as far as the general idea is concerned.

Although on the upper Rhine and upper Wahal the greatest depth is generally found in the parts presenting the strongest curves and the places of least depth near the changes in direction and in the straight parts, it has been found impossible to discover the relation between the extent of the bend and the depth, or between the distances between the points of greatest and least depth and the corresponding points where the curve is greatest or least.

In general however the bottom of the river, being composed of sand mixed with gravel, is so inconstant at this point that the above result is not astonishing.

An examination undertaken expressly for the purpose and based upon the results obtained by transverse soundings during the last six years has shown that the Wahal may be divided into two distinct parts:

1. The part commencing at the point of separation near kilometre 10 and extending as far as kilometre 44, where the movement of the regions of deep and shallow water undergoes but little modification and the condition of the bed of the river may be considered constant;

2. The part between kilometre 44 and the confluence with the Meuse (kilometre 94), in which a general movement in the bed of the river is observed in a down stream direction, both in deep and shallow places.

It is to be observed that this movement takes place at a rate which varies in different places between 250 and 500 m. annually, and it is independent of the form of the geometrical projection, that is to say the straight or curved course, where it is observed both in the convex and concave banks.

How far the works completed only last year, referred to above, influence this movement cannot yet be determined.

Translated by FRANCIS A. OLIVER.

Sixth International Inland Navigation Congress

THE HAGUE 1894.

GELDERSCHE YSSEL

BY

H. DOYER,

Engineer (3rd class) for Waterways, Zutphen.

On the programme of work proposed for the VIth International Inland Navigation Congress the sixth question refers to the correlation between curve and depth of water in river channels.

The Geldersche Yssel with its extremely winding course seemed to me very appropriate for the purpose of illustration and proof.

I had not time to study its whole length, and therefore chose six sections of it, each from 6 to 9 miles long.

Three of these sections contain sharp curves, viz.: The curve near Steeg village, Kilometre XI—XX;

The curve above Zutphen, Kilometre XXXIX—XLVII;

The curve near Veessen, Kilometre LXXX—LXXXVII.

In the other three sections, viz:

From Dieren to Brummen, Kilometre XXXII—XXXIX;

The curve above Deventer, Kilometre LIX—LXV; and

That near Deventer LXIV—LXXI,

the course of the river is less winding.

For several years past no regulating work of any importance has been carried out in these sections.

It may therefore be supposed that there is a stable bottom, as far as that is possible with a bed consisting of gravel, and a very irregular winter stream.

The article by Mr. FARGUE on the correlation between the line of bed

and depth of water in rivers having shifting bottoms has guided me in my study. The article referred to was published in the „Annales des ponts et chaussées, 4th serie 1868".

The graphical plans here annexed are generally composed in the same way as those of the article mentioned.

They show the width of the river during average height of flow, the minimum depth in a navigable channel not less than 15 metres wide and the curve of the course of the river.

I have also shown the normal width, fixed by decree May 23rd 1867.

The width is measured at the Kilometre, and at every 100 metre between.

On a chart on sufficiently large a scale $\left(\frac{1}{5000}\right)$ the course of the normal bed has been traced by drawing a line trough the points equally distant from the two banks. This line has been plotted ont into curved and straight lengths; the curves have been determined by a pair of compasses.

The depth of channel is drawn from the soundings of 1893.

The Kilometre limits, and the gauge-marks are indicated.

I have also given four water readings and shown the difference of level.

These four readings are:

The very high rise of January 1883.

The mean from 1871 to 1880.

The low water of January 1858.

The height when reading 1.50 metres at the Cologne gauge.

It is hoped to attrain in the channel 6 feet of water or a depth of about 1.70 m. at this last reading termed normal low water.

The wished-for depth is therefore that shown by the line traced 1.70 m. under the normal low water line.

I add that the volume of water discharged near Westervoort (Kilometre limit 0) by the Geldersche Yssel may be estimated.

At highest flood exceeding 4 metres above mean level, at	160 cub. m.
With normal waters, at	217 „ „
At normal low water, at	80 „ „

The lines in the graphical plans require no explanation.

In general the top curve indicates deep water whilst a straight stretch, and a change of direction indicate shallow water.

Necessarily also the width of the river influences the depth.

To decide wether that depth increases with the curvature I adopted the following plan.

The deep places and the shallows in obvious connection with the curve of the river are indicated on the plan by a number.

The point where the curve presents the feature to which the deep or the shallow water must be attributed is marked with the same number as the corresponding deep or shallow water.

For each so-numbered spot where the water is deep or shallow the following table gives:

a. The point of the curve to which the deep or shallow water must be attributed; the curve referred to being shown by the Kilometre limit given.

b. The position of the deep or shallow water.

c. Distance between *a* and *b*.

d. The radius of curve at *a*.

e. Width at *b*.

f. Normal width at *b*.

g. The width in hundredths of the normal width.

h. Depth at *b*, from the soundings of August 1893, reduced to mean water-level.

Number.	Points of maximum and of minimum. Kilom.	Deep and Shallow places. Kilom.	Distance apart of last named. Metres.	Radius of Curve Metres.	Width. Metres.	Normal Width. Metres.	Width in %age of normal width.	Depth. Metres.	*Observations.*
				Bend near Steeg village.					
1	11.5	11.66	160	325	80	103.5	77	4.15	
2	11.7	11.71	10	∞	80	103.5	77	3.45	Slight curve.
3	11.75	11.89	140	500	92	103.6	89	4.65	
4	11.8	12.26	460	∞	97	103.7	94	2.95	
5	12.34	12.68	340	185	85	103.8	82	6.35	
6	12.72	12.97	250	∞	95	103.9	91	3.25	
7	12.93	13.14	210	250	100	104	96	5.55	
8	13.02	13.28	260	∞	89	104.1	86	3.55	
9	13.34	13.48	140	275	96	104.2	92	5.95	
10	13.5	13.84	340	∞	120	104.2	115	2.75	
11	13.88	14.06	180	135	118	104.2	113	6.25	
12	14.9	15.26	360	∞	94	104.6	90	2.80	
13	15.65	15.86	210	300	94	104.8	90	6.25	
14	16.1	16.5	400	∞	122	105	116	2.80	
15	16.45	16.7	250	1000	106	105.1	101	3.80	
16	16.55	16.86	310	∞	108	105.2	103	2.80	
17	18.08	18.28	200	425	98	105.6	93	6.80	
18	18.4	18.42	20	∞	109	105.6	103	2.95	
19	18.57	18.67	100	750	100	105.7	95	4.80	
20	18.69	18.9	210	∞	100	105.8	95	3.25	
21	18.9	19.18	280	500	126	105.8	119	4.50	

Number.	Points of maximum and of minimum. Kilom.	Deep and Shallow places. Kilom.	Distance apart of last named. Metres.	Radius of Curve. Metres.	Width. Metres.	Normal Width. Metres.	Width in °/₀age of normal Width.	Depth. Metres.	*Observations.*
				Section from Dieren to Brummen.					
22	32.8	33.02	220	∞	107	110	97	2.80	
23	33.64	33.8	160	∞	97	110.2	88	3.10	
24	33.92	34.1	180	1250	113	110.3	102	3.85	
25	34.1	34.52	420	∞	100	110.4	91	2.75	
26	34.66	34.78	120	500	107	110.5	97	4.90	
27	34.73	35.08	350	∞	104	110.6	94	3.00	
28	35.1	35.24	240	210	93	110.7	84	5.05	
29	35.35	35.58	230	∞	97	110.8	88	3.25	
30	35.79	35.87	80	325	93	110.8	84	5.45	
31	35.9	36.18	280	∞	85	110.9	77	3.85	
32	36.24	36.26	20	450	88	111	79	5.25	
33	36.4	36.6	200	∞	97	111.1	87	3.45	
34	36.68	36.72	40	600	106	111.1	95	4.40	
35	36.85	37.17	320	∞	105	111.2	94	2.90	Slight curve.
36	37.1	37.42	320	475	113	111.3	102	4.45	
37	37.25	37.6	350	∞	110	111.4	99	3.35	
38	37.7	37.8	100	475	109	111.5	98	4.50	
39	38	38.2	200	∞	125	111.5	112	2.95	
40	38.25	38.33	80	750	115	111.6	103	3.80	
41	38.4	38.53	180	∞	110	111.7	98	2.90	
42	38.58	38.68	100	1750	109	111.7	98	3.75	
				Curve above Zutphen.					
43	39.75	39.76	10	300	92	112	82	5.70	
44	39.9	40.02	120	∞	87	112.1	78	3.50	
45	40.72	40.9	180	500	115	112.3	102	3.80	
46	40.85	41.05	200	∞	126	112.3	112	3.10	
47	41.09	41.28	190	375	112	112.4	100	5.70	
48	41.5	41.73	230	∞	73	112.6	65	3.65	
49	41.82	41.87	50	250	99	112.7	88	6.90	
50	42.2	42.4	200	∞	125	112.7	111	3.10	
51	42.35	42.5	150	750	115	112.8	102	3.80	
52	42.5	42.68	180	∞	112	112.9	99	2.75	Slight curve.
53	42.82	42.95	130	400	90	113	80	5.50	
54	42.93	43.23	300	∞	93	113	82	3.30	
55	43.38	43.63	250	750	106	113.1	94	4.30	
56	43.55	43.9	350	∞	85	113.2	75	3.15	
57	44.65	44.8	150	500	100	113.5	88	4.45	
58	45.1	45.2	100	∞	113	113.6	99	2.85	
59	46.1	46.4	300	375	101	114	89	5.50	

Number.	Point of maximum and of minimum. Kilom.	Deep and Shallow places. Kilom.	Distance apart of last named. Metres.	Radius of Curve. Metres.	Width. Metres.	Normal Width. Metres.	Width in %age of normal Width.	Depth. Metres.	*Observations.*
				Section above Deventer.					
60	59.12	59.33	210	375	102	118	86	6.50	
61	59.3	59.52	220	∞	98	118.1	83	3.45	Slight curve.
62	59.5	59.8	300	475	95	118.2	80	6.45	
63	59.7	59.98	280	∞	104	118.2	88	3.40	
64	59.82	60.1	280	2000	114	118.2	96	4.05	
65	60	60.2	200	∞	120	118.2	102	3.25	
66	60.1	60.38	280	250	95	118.3	80	7.30	
67	60.4	60.7	300	∞	110	118.3	93	3.50	Point of surflexion.
68	60.55	60.75	200	1000	110	118.4	93	3.95	
69	60.7	60.98	280	∞	113	118.4	95	3.20	
70	61.15	61.33	180	750	85	118.5	72	5.40	
71	61.4	61.62	220	∞	99	118.6	83	3.35	
72	61.7	61.95	250	2000	100	118.7	84	4.40	
73	61.9	62.15	250	∞	89	118.8	75	3.40	Slight curve.
74	62.08	62.36	280	500	83	118.9	70	5.85	
75	62.24	62.63	390	∞	78	119	66	3.75	
76	62.6	62.75	150	500	93	119	78	5.30	
77	62.8	62.98	180	∞	110	119.1	92	3.60	
78	63.03	63.18	150	750	105	119.1	88	5.35	
79	63.2	63.5	300	∞	108	119.2	91	3.30	
80	63.36	63.68	320	1000	120	119.3	101	3.60	
81	63.45	63.78	330	∞	127	119.4	106	3.10	
				Section near Deventer.					
82	64.4	64.72	320	∞	113	119.6	94	2.90	
83	65.2	65.15	÷ 50	400	113	119.7	94	5.50	
84	65.6	66.13	530	∞	130	120	108	3.00	
85	66.17	66.44	270	250	120	120.4	100	6.70	
86	66.24	66.75	510	∞	123	120.6	102	3.10	
87	66.7	66.9	200	400	120	120.8	99	3.90	
88	66.8	67.02	220	∞	115	120.9	95	3.55	
89	68.75	68.94	190	425	97	122.6	79	7.45	
90	68.9	69.2	300	∞	121	122.8	99	3.40	
91	69.67	69.82	150	500	110	123.2	89	5.20	
92	69.8	70.15	350	∞	116	123.5	94	3.25	
93	70.4	70.6	200	750	113	123.9	91	4.95	
				Bend near Veessen.					
94	80.95	81.15	200	250	120	133	90	5.20	
95	81.05	81.4	350	∞	122	133.2	92	3.80	
96	81.9	82.27	370	∞	118	133.9	88	3.15	

Number.	Point of maximum and of minimum. Kilom.	Deep and Shallow places. Kilom.	Distance apart of last named. Metres.	Radius Curve. Metres.	Width. Metres.	Normal Width. Metres.	Width in °/₀age of normal Width.	Depth. Metres.	*Observations.*
97	83	83.25	250	∞	124	134.8	92	3.00	
98	83.17	83.36	190	2000	115	134.9	85	4.50	
99	83.24	83.66	420	∞	130	135.1	96	2.95	
100	83.5	83.75	250	2000	130	135.2	96	4.00	
101	83.6	84.23	630	∞	125	135.6	92	2.85	
102	84.2	84.28	80	5000	125	135.6	92	3.45	
103	84.3	84.55	250	∞	125	135.9	92	2.85	
104	85	85.1	100	2000	134	136.4	98	3.40	
105	85.15	85.5	350	∞	140	136.7	102	2.70	
106	86.28	86.53	250	500	107	137.6	78	5.70	
107	86.4	86.85	450	∞	145	137.9	105	2.80	

As the places where the water is deep are met with at some distance below the top of the curves, so likewise the shallows are found some way down the straight parts or below the changing of direction (loi de l'êcart). The average of this distance is 233 metres.

From the above tables is deduced the following table in which the depths are arranged in order of length of radius of curve and of the mean normal width of the main channel.

Depth of main channel in $^1/_{100}$ths of Normal Width.	Radius of curve									
	135	185	210	250	275	300	320	375	400	425
	Depth in metres below									
65	—	—	—	—	—	—	—	—	—	—
66	—	—	—	—	—	—	—	—	—	—
67	—	—	—	—	—	—	—	—	—	—
68	—	—	—	—	—	—	—	—	—	—
69	—	—	—	—	—	—	—	—	—	—
70	—	—	—	—	—	—	—	—	—	—
71	—	—	—	—	—	—	—	—	—	—
72	—	—	—	—	—	—	—	—	—	—
73	—	—	—	—	—	—	—	—	—	—
74	—	—	—	—	—	—	—	—	—	—
75	—	—	—	—	—	—	—	—	—	—
76	—	—	—	—	—	—	—	—	—	—
77	—	—	—	—	—	—	4.15	—	—	—
78	—	—	—	—	—	—	—	—	—	—
79	—	—	—	—	—	—	—	—	—	7.45
80	—	—	—	7.30	—	—	—	—	5.50	—
81	—	—	—	—	—	—	—	—	—	—
82	—	6.35	—	—	—	5.70	—	—	—	—
83	—	—	—	—	—	—	—	—	—	—
84	—	—	5.05	—	—	—	5.45	—	—	—
85	—	—	—	—	—	—	—	—	—	—
86	—	—	—	—	—	—	—	6.50	—	—
87	—	—	—	—	—	—	—	—	—	—
88	—	—	—	6.90	—	—	—	—	—	—
89	—	—	—	—	—	—	—	5.50	—	—
90	—	—	—	5.20	—	6.25	—	—	—	—
91	—	—	—	—	—	—	—	—	—	—
92	—	—	—	—	5.95	—	—	—	—	—
93	—	—	—	—	—	—	—	—	—	—
94	—	—	—	—	—	—	—	—	5.50	6.80
95	—	—	—	—	—	—	—	—	—	—
96	—	—	—	5.55	—	—	—	—	—	—
97	—	—	—	—	—	—	—	—	—	—
98	—	—	—	—	—	—	—	—	—	—
99	—	—	—	—	—	—	—	—	3.90	—
100	—	—	—	6.70	—	—	—	5.70	—	—
101	—	—	—	—	—	—	—	—	—	—
102	—	—	—	—	—	—	—	—	—	—
103	—	—	—	—	—	—	—	—	—	—
104	—	—	—	—	—	—	—	—	—	—
105	—	—	—	—	—	—	—	—	—	—
106	—	—	—	—	—	—	—	—	—	—
107	—	—	—	—	—	—	—	—	—	—
108	—	—	—	—	—	—	—	—	—	—
109	—	—	—	—	—	—	—	—	—	—
110	—	—	—	—	—	—	—	—	—	—
111	—	—	—	—	—	—	—	—	—	—
112	—	—	—	—	—	—	—	—	—	—
113	6.25	—	—	—	—	—	—	—	—	—
114	—	—	—	—	—	—	—	—	—	—
115	—	—	—	—	—	—	—	—	—	—
116	—	—	—	—	—	—	—	—	—	—
117	—	—	—	—	—	—	—	—	—	—
118	—	—	—	—	—	—	—	—	—	—
119	—	—	—	—	—	—	—	—	—	—
120	—	—	—	—	—	—	—	—	—	—

in metres.

450	475	500	600	750	1000	1250	1750	2000	5000	∞
Normal Water Level.										
—	—	—	—	—	—	—	—	—	—	3.65
—	—	—	—	—	—	—	—	—	—	3.75
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	5.85	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	5.40	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	3.40, 3.15
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	3.85, 3.45
—	—	{ 5.70 5.30	—	—	—	—	—	—	—	3.50
5.25	—	—	—	—	—	—	—	—	—	—
—	6.45	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	3.30
—	—	—	—	—	—	—	—	—	—	3.45
—	—	—	—	—	—	—	—	4.40	—	—
—	—	—	—	—	—	—	—	4.50	—	—
—	—	—	—	—	—	—	—	—	—	3.55
—	—	—	—	—	—	—	—	—	—	3.45
—	—	4.45	—	5.35	—	—	—	—	—	3.40 to 3.10
—	—	{ 5.20 4.65	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	2.80
—	—	—	—	4.95	—	—	—	—	—	3.30 to 2.75
—	—	—	—	—	—	—	—	—	3.45	3.80 to 2.85
—	—	—	—	—	3.95	—	—	—	—	—
—	—	—	—	4.30	—	—	—	—	—	—
—	—	—	—	4.80	—	—	—	—	—	3.55 to 3.20
—	—	—	—	—	—	—	—	{ 4.05 4.00	—	2.95
—	—	4.90	—	—	—	—	—	—	—	2.80
—	4.50	—	—	—	—	—	3.75	3.40	—	2.90
—	—	—	—	—	—	—	—	—	—	3.40, 2.75
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	{ 3.80 3.60	—	—	—	—	—
—	4.45	3.80	—	3.80	—	3.85	—	—	—	3.25 to 2.70
—	—	—	—	3.80	—	—	—	—	—	2.95, 2.80
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	2.80
—	—	—	—	—	—	—	—	—	—	3.10
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	3.00
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	3.10
—	—	—	—	—	—	—	—	—	—	3.10, 2.95
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	2.75
—	—	—	—	—	—	—	—	—	—	2.80
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	4.50	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—

It is evident that, the depth depending exclusively on the curve and the width, the figures in the foregoing table will decrease from top downwards and from right to left.

Such is generally the case.

Hence it may bo taken that the depth increases as the curves become sharper and the width smaller.

The deviations from this rule are however of such a character that it would not be prudent to draw from the figures above given a mathematical formula for the relation between depth, width and curve.

Remembering that the proposed depth is 3 metres below the normal mean level, it may be deduced from the figures in the table above that, the fixed normal width is too great in the straight stretches and in those places where the curve is insignificant or null.

When the width of these sections is 90 $^0/_0$ or less of the fixed normal width, the required depth is found in the channel.

For this reason is it that in the straight stretches and near the points of change of direction of the course of the Geldersche Yssel, the width of the bed will be reduced to 90 $^0/_0$ of the normal width.

VI^th International Inland Navigation Congress

THE HAGUE. 1894.

THE PANNERDEN CANAL, LOWER RHINE AND LECK.

BY

J. G. ERMERINS,

Engineer (2nd cl.) of Waterstaat, Utrecht.

The navigable waterway formed by the Pannerden canal, the Lower Rhine and the river Leck is an arm of the Upper Rhine, springing from it at Pannerden and joining the New Meuse near Krimpen. Opposite Huissen this arm bifurcates and of the two streams one bears the name of the Lower Rhine whilst the other is termed the Yssel.

The following table shows the principal water levels:

	Pannerden.	Arnhem.	Grebbe.	Wijk bij Duurstede.	Culemborg.	Vreeswijk.	Schoonhoven.	Krimpen.
Distance from the Frontier in km.	12865	25905	49960	69605	81495	92225	113610	130640
Reading of normal Low-water (N. L. W.) on the Cologne base of 1.50 m.	8.92	7.68	5.29	3.38	2.22	1.41	0.20	— 0.45
Low-water Level of 1874. . .	8.18	7.02	4.71	2.76	1.62	0.76	— 0.21	— 1.00
Mean Level (May 1st to Oct.r 31st 1871—1880)	10.14	8.80	6.29	4.47	3.23	2.34	H. W. 1.24 L. W. 0.70	H. W. 0.73 L. W. — 0.40
High-water Level of 1883 . .	14.64	13.06	10.65	8.31	7.19	6.30	4.45	2.18

The volume of water discharged per second may be estimated as follows, in cubic metres:

	PANNERDEN-CANAL.	LOWER RHINE NEAR ARNHEIM.
At 1 metre below mean water level	330	200
At mean water level	620	410
„ 1 metre above mean water level	950	660
„ 2 „ „ „ „ „	1340	950
„ 3 „ „ „ „ „	1790	1300

The volume of water discharged at the „Oude Rijnmond" was 479 cub. m. with a fall of 1.32 m.

According to the agreement of May 23[nd] 1867, the width at the Summer normal level is fixed at:

From Pannerden to the month of the Yssel	170 m.
Thence to Wijk bij Duurstede	160 „
Widening out to the South Holland frontier to	170 „
Thence again to Vreeswijk	170 „
Thence again widening out to Krimpen	200 „

(Later fixed at 225 m.)

The winter width is fixed at 450 m., increasing between Pannerden and Vreeswijk to 500 m., and 500 m. between Vreeswijk and Krimpen; at the level of 2 metres above the normal and 1.50 m. above high water level.

The work undertaken for the purpose of giving to the summer bed the above named necessary width is not yet quite completed.

To secure the desired depth of 2 metres at normal low water in a channel of sufficient width for navigation, it has been found that the width must be reduced in the straight or nearly straight stretches.

From Pannerden to the mouth of the Yssel the depth is almost sufficient. From there to Eck and Wiel the normal width will be made 130 m., and forward to Vreeswijk be gradually increased to 163 m. The narrowing down will be carried out only in the straight or nearly straight lengths of river, where in late years there has been an insufficient depth of water: and also in a few curves of considerable length where the depth has been found deficient, as in the long straight stretches.

This last named abnormal circumstance has probably been brought about or contributed to by some local peculiarity, such as height of bank, proximity of dike, nature of soil, general ground slope etc., all of which so greatly affect the form of the river channel that special and unusual

means must often be adopted to secure the necessary depth at the least cost.

In the tidal stretch of river between Vreeswijk and Krimpen a depth of 2.50 m. at normal low water is required. Though the full depth is not yet secured it is already much better than above Vreeswijk.

In the accompanying table the depths, widths and bends are shown, from the mouth of the Yssel to the 28 km. limit. The red line shows the width after the regulating work now in progress has been completed. When finished the smallest radius will be 230 metres.

The greatest depths are generally found at, or immediately below, the sharp bends.

On the whole, however, there is so little uniformity that hitherto it has been impossible to fix any very definite proportion between the curvature and depth of water. This must be left over until the work now being done is terminated, when there will probably be much greater regularity of channel.

VIth International Inland Navigation Congress.

THE HAGUE, 1894.

Remarks upon the depth of the Upper Meuse

BETWEEN

MOOK AND HEDEL.

BY

R. TUTEIN NOLTHENIUS,

Waterstaat-Engineer at Bois-le-Duc.

INTRODUCTION.

The administration of the fifth division of rivers comprises a section of the Upper Meuse about 100 km. in length. This section extends from Mook to Woudrichem where the Meuse joins the Waal.

As the influence of the tide is felt at Hedel (24 km. above the mouth), it seemed preferable to limit this study to the section between Mook and Hedel, a distance of 72800 m.

In this part of its course the river receives no tributary so that the discharge is everywhere the same, except at the time of the highest floods when two natural watercourses (Beers and Heerewaarden) come into operation. But these cases are sufficiently rare and their influence may be regarded as secondary.

The discharge corresponding to the average water-level of the summer season (May to October) during the ten years 1881—90 is 180 cub. m. per second. The discharge corresponding to the probable water line (that is the line that is passed as often as not reached) is 235 cub. m. per second. This line is generally half a metre above the summer level already mentioned.

The natural banks of the summer bed are rather steep and the river only begins to overflow when the water line reaches an average level of 3 m. above the summer level.

The discharge is then 765 cub.m. per second. The water-line often remains for several weeks (sometimes, but rarely, six weeks running) above this comparative level. Even a level half a metre above this is sometimes exceeded during a whole month (this level corresponds to a discharge of 965 cub.m. per second).

But higher floods are rare and quickly subside and it is only quite exceptional that the level rises half a metre higher and the discharge amounts to 1500 cub.m. per second.

The incline per kilometre at the level of the average summer waters is very inconsiderable. The average is 0.0618 m. and varies from 0.047 m. to 0.0753 m.

This incline increases very slightly with an increase in the discharge. During the highest floods the average incline per kilometre amounts to 0.08 m.

The consequence is that the average velocity is not considerable. The velocity corresponding to the mean summer discharge (185 cub. m.) hardly amounts to 0.50 m. per second; it gradually increases to 1 m. per second until the summer bed is filled without increasing to any considerable extent in time of floods.

The cross sections of the summer bed between Mook and Hedel were taken last year at distances of 100 m. apart. Soundings were take every 5 m.

With the help of these data it was possible to obtain the longitudinal section A copy of this drawing (in three sheets) is placed at the disposal of the Congress.

On this longitudinal section is traced a horizontal line representing the average water-level of the summer season during the ten years 1881—90. The comparative average depth of the section is carried below this line as well as the minimum depth of the channel of navigation and the maximum depth of the section.

The width of the summer bed is carried above this horizontal line. At the foot of the drawing are straight lines on either side of a horizontal axis at distances equal to $\frac{1}{r}$ of the summer bed. The artificial banks are indicated by cross-hatching along these lines.

§ 1. WIDTH OF THE SUMMER BED.

In places where the dwellers on the river banks protect their lands from the effects of the current by means of groins of considerable length (generally perpendicular to the banks), the heads of the groins determine the width. It is equally the case where the State builds the groins to confine the summer bed.

These artificial banks extend over 40 km., or more than half the distance between Mook and Hedel. (The sections where only one of the banks is artificial are included in this total length.)

Everywhere else the width of the summer bed is measured between the natural banks. These banks are formed of clay soil and have a steep incline at 2.50 m. to 3.50 m. above the mean summer water-mark.

The width taken in this way varies from one section to another within very narrow limits. When all the parts in whioh the width only varies between 120 and 140 m. are added together it is found that they form more than half ($^5/_9$) of the total length; the parts in which the width varies between 120 and 100 m. form together $^1/_6$ of the total length and the same is the case where the width varies between 140 and 160 m.

It follows that the average width is practically 130 m.

§ 2. CHANNEL OF NAVIGATION.

It results from the requirements of navigation that the navigable channel must have an almost uniform width of 40 m. As the minimum depth of the channel determines its use it is necessary to consider this minimum as the depth proper of the channel.

The channel is marked in such a manner that it can be used for navigation; the result is that in certain places (that is to say in the shallows) the depth of the channel is less than the mean depth of the summer bed; naturally this difference is not considerable.

§ 3. CURVES.

The curvature in the summer bed is very variable; moreover the curve is often sharper at the apex.

The total number of curves is 45, curves with a radius of 3000 m. or more being regarded as straight lines. The total length of the curves forms $^5/_8$ of the distance.

By taking as a unite of comparison the mean width of the summer bed ($b = 130$ metres), it appears that a third of the curves have at their apex a radius less than $5\,b$, a third have at their apex a radius of $5\,b$ to $10\,b$, while the radius of the remaining third is from to $10\,b$ to $20\,b$ in length.

When the curves are classified according to their length it is found that more than one third (19) of the total number have a length less than $5\,b$, that almost a third have a length of $5\,b$ to $10\,b$, while the length of the remaining third is from $10\,b$ to $20\,b$.

(It is to be remarked that the two series have no connection).

§ 4. STRAIGHT PORTIONS.

Two thirds of the curves are separated by straight portions more or less long. Eleven curves (about $^1/_4$ of the total number) change their direc-

tion without this change being preceded by an intermediate rectilinear section, while in 4 cases the curves are only separated by less pronounced curves without a change in direction.

In almost all ($^5/_6$) the straight portions the length of the straight line is less than $5\,b$.

§ 5. RELATION BETWEEN THE WIDTH AND THE MEAN DEPTH OF THE TRANSVERSE SECTION.

It is important to examine first the relation existing between the width, the mean depth and the curve.

In order to determine this relation all the transverse sections are arranged in five categories.

1st Category. —	Straight lines and curves with a radius of more than 2000 m.	
2nd "	Curves of a radius of 2000 m. to 1500 m.	
3rd "	" " " " 1500 " " 1000 "	
4th "	" " " " 1000 " " 700 "	
5th "	" " " " less than 700 "	

By tracing the width on one of the two axes of a system of coordinates and on the other the average depth of each cross section of the summer bed, a diagram may be traced for each category representing the relation between these two values.

The diagrams are almost rectilinear, they are evidently parallel and very close together (1).

From this the following rule may be deduced:

RULE I. *The average depth of the summer bed depends almost entirely upon the width; the influence of the radius of the curve may be neglected.*

By taking an average from three diagrams it is found that

a mean depth of 3.40 m. corresponds to a width of 100 m.
" " " 2.89 " " " " " 120 "
" " " 2.43 " " " " " 140 "
" " " 2.05 " " " " " 160 "
" " " 1.70 " " " " " 180 "

(1) In order to allow of personal investigation, the following coordinates have been obtained from these drawings:

ABSCISSAE.	ORDINATES.				
	1st Category.	2nd Category.	3rd Category.	4th Category.	5th Category.
Width of 100 m.	2.97 m.	3.08 m.	3.21 m.	—	—
" " 120 "	2.66 "	2.70 "	2.81 "	3.08 m.	3.22 m.
" " 140 "	2.35 "	2.32 "	2.41 "	2.52 "	2.56 "
" " 160 "	2.04 "	1.94 "	2.01 "	2.11 "	2.14 "
" " 180 "	1.73 "	1.56 "	1.61 "	1.76 "	—

By multiplying the width b by the corresponding mean depth h it is found that when

$b =$ 100 m.	$I = b \times h =$ 346 sq. m.
120 „	347 „
140 „	340 „
160 „	328 „
180 „	308 „

A width of 160 m. or more being exceptional it follows that the following rule may be practically admitted:

RULE II. *The product of the width and mean depth of the minor bed is constant.*

This product I *is equal to* 340 *sq. m.*

§ 6. RELATION BETWEEN THE RADIUS OF THE CURVE AND THE DEPTH OF THE CHANNEL OF NAVIGATION.

According to Rule I the mean depth of the summer bed depending only on the width, it seems reasonable to eliminate this element as far as possible in seeking to determine the relation between the radius of the curve and the depth of the channel of navigation by examining, instead of the absolute depth, the difference between the depth of the channel h_n and the mean depth of the summer bed h.

For this purpose 4 categories have been established. In the first are classed all transverse sections the width of which varies between 100 m. and 120 m., the second contains the sections whose width varies between 120 and 130 m., the third those whose width varies between 130 and 140 m., while in the last are classed all transverse sections whose width varies between 140 and 160 m.

By placing $\frac{1}{r}$ upon one of the two axes of a system of coordinates and on the other the difference between the two depths $(h_n - h)$, a line may be traced in each category representing the ratio between these two values.

These diagrams have a very slight curvature, they are evidently parallel and very near together (1).

(1) In order to allow of personal investigation the following coordinates have been taken from these drawings:

ORDINATES.	ABSCISSAE.			
	$h_n - h$	$h_n - h$	$h_n - h$	$h_n - h$
$\frac{1}{r}$	$b =$ 100 to 120 M.	$b =$ 120 to 130 M.	$b =$ 130 to 140 M.	$b =$ 140 to 160 M.
$r = \infty$ M.	0.00 M.	0.08 M.	0.045 M.	0.09 M.
2000 „	0.16 „	0.26 „	0.34 „	0.30 „
1000 „	0.32 „	0.44 „	0.55 „	0.47 „
500 „	0.65 „	—	—	—

From this the following rule may be drawn:

RULE III. *The difference between the depth of the channel and the mean depth of the summer bed depends almost entirely upon the radius of the curve; the influence of the width of the summer bed may be neglected.*

This rule enables us to strike an average of the 4 catogories; it is then found that the amount of the difference $(h_n - h)$ is:

in the rectilinear portions.	0.064 m.
" curves with a radius of 2000 m.	0.265 "
" " " " " 1000 "	0.445 "
" " " " " 500 "	0.700 "

This relation is represented sufficiently exacty by the following formula in which the values are expressed in metres.

Law of difference.

$$h_n - h = 0.06 + \frac{400}{r} - \left(\frac{200}{r}\right)^2 \quad \ldots\ldots \quad 1).$$

§ 7. APPLICATION OF PRECEDING RULES.

By multiplying both sides of equation (1) by b and applying Rule I, according to which $h\,b$ is constant and therefore equal to $H\,B$ (H = mean depth of summer bed and B = width in the definitely normalised rectilinear portions), it is found that:

$$b = \frac{H\,B}{h_n - 0.06 - \frac{400}{r} + \left(\frac{200}{r}\right)^2}$$

But the width of the river in the curves should be such that h_n becomes equal to H_n (H_n representing the depth of the channel in the normalised rectilinear portions); therefore:

$$b = \frac{H\,B}{H_n - 0.06 - \frac{400}{r} + \left(\frac{200}{r}\right)^2}$$

By making r in (1) equal to infinity we have

$$H_n - H = 0.06.$$

therefore: $$b = \frac{H\,B}{H - \frac{400}{r} + \left(\frac{200}{r}\right)^2} \quad \ldots\ldots\ldots\ldots \quad 2)$$

In the section of the Meuse which forms the subject of this study it seems reasonable to make $H = 3$ m.

The width in the curves should therefore be the following:

$r = 4000$ m.	$b = 1.034\ B$
2000 „	$1.068\ B$
1000 „	$1.137\ B$
500 „	$1.271\ B$

This relation is shown sufficiently exactly by the following formula:

$$b = B\left(1 + \frac{135}{r}\right) \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad 3)$$

It was found above (§ 5) that $I = 340$ m., from which it follows that the normal width B in the rectilinear portions of the summer bed should be equal to

$$\frac{340}{H} = \frac{340}{3} = 113 \text{ m.}$$

Therefore in curves with a radius equal to five times the normal width ($5\,B$) the width must be increased by about one quarter ($^5/_4\,B$).

In the present state of the summer bed the radius of curves is often less than $5\,B$ (see § 3), but it is better not to admit curves of a smaller radius.

§ 8. LAW OF DIGRESSION.

The distance from the apex of the curve to the point of maximum depth in the corresponding hollow (i. e. where h_n has a maximum value) is for the part of the Meuse which forms the subject of this study independent of the radius of the curve at the apex. This is contrary to the observations of M. Fargue on the Garonne. It depends only on the width of the river where the radius is least and is equal to double this width (1). It is perhaps unnecessary to mention that the sections upon which this study is based were only taken at distances of a hundred metres.)

---

(1) The following table shows the average values of the ratio $\left(\frac{l}{b}\right)$ between the width b at the apex of the curve and the distance l from the apex to the maximum depth of the corresponding hollow:

$r =$ (in metres)	3000	2750	2000	1600	1400	1250	1000	900	750	700	625	575	550	500	425	375	275
$\frac{l}{b} =$	0.85	0.7	2.2	1.6	1.5	1.3	2.00	3.3	3.1	1.5	2.5	2.5	1.5	1.7	1.5	2.8	2.6

By placing in a system of coordinates the value of $\frac{1}{r}$ on one axis and the value of $\frac{l}{b}$ on the other a broken line is obtained for which may be substituted a straight line parallel to the axis of $\frac{1}{r}$ at a distance $2\,b$.

The distance from the point where the direction changes to the corresponding shallow (i. e. the point where h_n has a minimum value) is subject to the same law. Only this distance is generally smaller and is equal to 1.8 times the width at the point where the direction changes (1).

A deeper study for which unfortunately the necessary time is wanting would probably reveal many other facts.

---

(1) The following table shows the average values of the ratio $\left(\frac{l}{b}\right)$ between the width of the summer bed at the change in direction and the distance l from this point to the minimum depth of the corresponding shallow. The radius indicated in this table is that of the curve immediately below the change in direction.

r = in metres	6500	2750	2000	1750	1600	1400	1100	1000	750	700	550	500	400	375	275
$\frac{l}{b}$ =	0.75	2.4	1.3	2.9	2.05	1.3	1.85	1.95	3.35	0.8	1.00	1.75	2.2	1.4	1.4

By placing in a system of coordinates the value of $\frac{1}{r}$ on one axis and the value of $\frac{l}{b}$ upon the other an irregular line is obtained for which may be substituted a straight line parallel to the axis of $\frac{1}{r}$ at a distance of 1.8 b.

Translated by Francis A. Oliver.

VI[th] International Inland Navigation Congress.

THE HAGUE 1894.

Relations between the configuration of rivers and the depths of their channels.

BY

C. B. SCHUURMAN,

AND

H. L. VAN HOOFF,

Engineers of the Waterstaat.

I. INTRODUCTION.

In reply to the sixth question we will examine in the following lines if the observations gathered in the last years concerning tidal rivers, such as the Upper Merwede, the Lower Merwede, the New Merwede, the Old Maas and the Dordrechtsche Kil can serve as a basis for the deduction of the relations existing between the configuration of rivers and the depths of their channels.

The four attached plates, I to IV, contain diagrams referring to the above-named rivers.

Plate I shows the Lower Merwede, the Old Maas and the Dordrechtsche Kil and the following factors of importance of these navigable rivers:

1°. The line of the curves.

2°. The width of the summer bed.

3°. The position of the channel in the summer bed.

4°. The greatest depth of the channel.

5°. The transverse section at half tide.

6°. The usual high water and the usual low water level.

With regard to the line of curve it should be observed that in order to correctly judge it, it must be considered in relation to the width of the river.

In the diagram the curves are indicated by the values $\frac{b}{R}$, in which b

is the width of the summer bed and R the radius of the curve of the axis of the river.

In composing the diagrams of the Upper Merwede and of the New Merwede a difficulty has been met with in the fact that the bottoms of those rivers have no stability.

While the factors mentioned above under 1°, 2° and 6° are constant, the depths, the sections of water and the position of the channel in the summer bed vary periodically.

In the Lower Merwede it is only the depths and the sections of water which vary, the channel keeping a fixed place in the bed.

The service of the Waterstaat has made soundings annually during the last 15 tot 18 years; the charts of these soundings show clearly the changes, which have taken place in the bottom.

The changes are, as we have said above, periodical, and the laws, which they follow are represented in the diagrams of the Plates II and III, which have been collected at intervals of two years on the Upper Merwede and the New Merwede.

The Old Maas and the Dordrechtsche Kil are of regular depths, as the current carries away at every point as much solid matter as it brings.

II. BRIEF OBSERVATIONS ON THE ABOVE-NAMED RIVERS.

The following remarks may form in some sense a supplement to the general report of the programme.

a. The Upper Merwede.

(See Plates II, III and IV).

Before the most recent improvements, which were executed to ensure a sufficient depth of water for navigation and a continuous channel for the discharge of ice, also, in view of the suppression of the Upper Maas, the condition of the Upper Merwede was: length 9 Km., width 600 m.

This width is limited by longitudinal dikes.

The curves and the width do not correspond to the system of the river.

The windings of the summer bed follow lines which do not in any way correspond with the curves of the river and form divided streams along the entire course.

While the sections of the water-level are about equal the depth varies very much.

Along both banks there are deep hollows at distances of 2500 to 3000 m. from each other (See Pl. III), of a depth of 8 to 14 and even 18 metres, while the depth between these channels is only 2 tot 3 metres. They run in zig-zag lines.

In the middle of the stream are shallows, rising from 0 tot 1 m. above A. P., (datum line of Amsterdam).

The stream flows as follows:

At the end of each hollow the current is divided; a part follows the bank, while another part crosses the stream between two shallows to the opposite bank where it joins the water flowing from a higher channel.

Thus, the lower end of each hollow is the commencing point of a division of the water and each upper end the point of union of two streams.

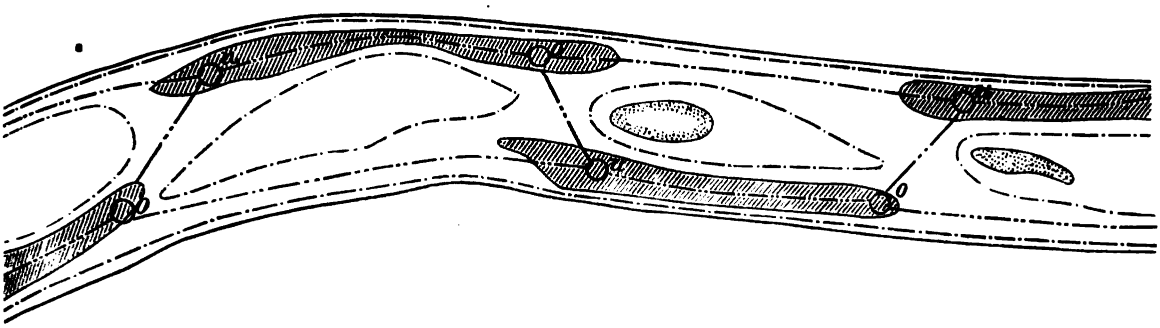
This explains the stability of the pools, for if the stream was single and regular they would soon be filled up.

In fact, the water flowing along the bank forms with the stream across the bed another current, which is directed against the bank.

There exist, thus, here the same conditions, which cause and maintain deep channels along concave banks.

A little distance lower down another division is produced because in deep channels the water has less fall than in shallow channels.

Let us suppose a regular flowing surface, which generally, corresponds with the water-level, and we shall find that, as the relative flow is not equally strong at every point, certain parts of the water-level will be higher and others lower than the supposed surface. We will indicate the higher parts by *U* and the lower with *O*. It is clear that at the upper end of a hollow there will always be found a point *O* and at the lower end a point *U*.



If there were no cross streams, the flow of water of every channel along the bank would remain constant.

The different depths cause corresponding variations in the flow and a section is formed, in which the inequality in the height of the water on the two banks must become the cause of a flow of water from one bank to the other. Near such a section we find again two points *U* and *O*.

The cross currents tend to diminish the irregularity of the flow along each bank and it may be supposed, that with a certain form of bottom,

a certain corresponding flow and incline of water might be obtained.

Meanwhile, the whole configuration of the bottom with channels and shallows moves regularly down stream.

At every point *U*, where the stream encounters an elevation of the bottom, there is scouring, and sand is carried away by the flow and deposited in the region of the point *O*.

It is evident, that the configuration of the bottom being the result of a certain equality of power keeps the same during its removal downstream.

Plate III, the graphic represention of depths on Plate II and of the channels on Plate IV show the regularity with which the movement of the bottom is followed.

The rate of the displacement is about 300 metres per year; and after a lapse of 9 to 10 years each channel occupies the place of the preceding one.

It is remarkable, that at places where there is a cross stream and a least depth of water the section of the profile is the greatest.

The annual volume of solid matter carried away yearly by the bottom movement may be easily calculated.

The north channel between the kilometerstones 97 and 99 has an average volume of.		865 000 cub. m.
The south channel between the kilometerstones 95 and 97 has an average volume of.		760 000 " "
The volume of the two shallows nearest to above channel is respectively	430 000	
and	495 000	
together		925 000 " "
Total		2550 000 cub. m.

All channels and shallows are after a lapse of 9 years again in their previous conditions. Thus, the stream carries away in 9 years 2550 000 cub. metres or about 270 000 cub. metres per year.

By means of much dredging in the last 5 years the channel along the northern bank has been maintained over all its length at a width of 250 to 300 metres.

In the course of this work about 2750 000 cub. metres have been dredged out.

By making the width of the river 450 m. in its upper part and 500 meters in its lower part, it is hoped that this favourable condition will be maintained in the future.

The last diagram on Pl. II shows the condition of the river in 1894, after the part above kilometerstone 99 had been reduced in the previous year to this width.

b. The Lower Merwede.

(See Pl. I).

Length 15 Km.

Width 200 m.

The channel has a fixed position in the bed.

The depths show variations.

The depths and the area of cross sections given on Plate I are the averages of the years 1886 to 1893.

As on the Upper Merwede the maxima and the minima of depth move towards the lower part of the stream. A continuation of the hollows of the Upper Merwede is observable; and the distances between the maxima and the minima are regular and constant during the displacement.

These distances are about 1800 m., and the displacements are such that after a lapse of 6 years the same depths are again found in the same sections. The displacement is thus $\frac{1800}{6} = 300$ m. per year.

The condition of the stream is favourable and the depth is maintained by the action of the current itself.

Since 1885 no dredging of importance has been effected on the Lower Merwede.

The volume of the bed below A. P. was.

in		
1885	. . . .	15 000 000 cub. metres.
1886	. . . .	15 000 000 „ „
1887	. . . .	14 600 000 „ „
1888	. . . .	15 400 000 „ „
1889	. . . .	16 000 000 „ „
1890	. . . .	15 500 000 „ „
1891	. . . .	14 600 000 „ „
1892	. . . .	15 200 000 „ „
1893	. . . .	15 200 000 „ „

The sand from upstream is regularly carried away.

The upper mouth is periodically shallow, and always when there is a deep channel on the right bank of the lower course of the Upper Merwede.

The sand which is carried away by the displacement of these channels (see Upper Merwede) settles in the upper mouth of the Lower Merwede.

This was first remarked in 1883—84 and is at the present time 1893—94 still observable, This corresponds with the phases of bottom displacement in the Upper Merwede.

c. The New Merwede.

(See Pl. II).

Length 20 Km.

Width 450 to 700 m.

The variations in the part of the river above kilometerstone 113 are a continuation of those observed on the Upper Merwede,

The channel has no fixed position in the bed. The cross streams are regularly displaced at the rate of 500 m. per year. After a lapse of 10 to 12 years the river is found again in the same condition.

Below the kilometerstone 113 the channel is very constant both as regards depth and its position in the bed.

About 17 000 000 cubm. have been dredged for the improvement of the river.

d. The Old Maas.

(*See Pl. I.*)

Length 29 Km.

Width 135 to 500 m.

The river has several curves which are connected well with one another, and show clearly the correspondence between the maximum and the minimum curves and depth.

e. Dordrechtsche Kil.

(*See Pl. I.*)

Length 9 Km.

Width 150 to 250 m.

In the interest of the maritime navigation a continuous channel of 6 m. under low-water has been dredged as far as Dordrecht. The river is very constant and tends to deepen, notwithstanding that the proportion of the depth to the width is here much greater than on the other rivers under our notice.

The proportions between the depth and the width of the following rivers are:

Upper Merwede	0.6 to 0.7	pCt.
Lower "	2.25 to 3.50	"
Old Maas	1.33 to 1.75	"
New Merwede-Upper part	0.5 to 0.7	"
" " -Lower "	0.85	"
Dordrechtsche Kil	4.25	"

The great depth must be ascribed to the strong ebb, which is caused by high water being maintained for some time at the northern mouth of the Kil by the flood current of the Old Maas, while at the same time it is ebb tide at the southern mouth. This increases and maintains the flow of the water.

III. CONCLUSIONS.

a. For rivers with a constant bottom.

The rivers we are considering belong to those, which form the delta of the Waal and the Maas. With regard to width, flow and tides they are so different, that they scarcely form a suitable basis for an examination and comparison of the above-mentioned factors.

There are too few curves in accordance with the system of the stream

to allow of a graphic represention of the proportions to be made, as was done by Mr. FARGUE on the Garonne.

The diagrams, however, lead to some conclusions.

1°. In general, the rules laid down by Mr. FARGUE are confirmed.

The exceptions are mostly due to the want of agreement of the curves and widths with the system of the river, or to a succession of unfavourable curves.

The curves, which do not correspond with the system are graphically represented by the want of accordance of the lines 1 and 3 (See Pl. I).

Examples.

All the cross streams in the Upper Merwede in the years 1882, 1884, and 1886 (See Pl. II).

Lower Merwede near the kilometerstones 111 and 116.

Dordrechtsche Kil near the kilometerstone 124.

2°. There is a divergence between the points of inflexion of the axis of the river, and those of the channel; the latter coincide, however, with those of the minima of depth.

This leads us to the following considerations:

At the point where the channel crosses the stream, the section has the form of a quadrangle or of a trapeze, while where the channel runs along one of the banks the section is triangular.

It will be seen from the diagrams that the areas of sections vary very little, even when the depths are very unequal.

It is evident that when the areas are nearly equal, the triangular sections show a greater depth than the quadrangular.

Thus, the maxima and the minima of depth are due to the form of the section; this form depends on the position occupied by the current, while the latter is influenced by the horizontal configuration of the summerbed.

3°. Observations on these rivers do not show that certain winding curves are necessary to the conservation of a regular depth.

Examples.

The Lower Merwede between the kilometrestones 105 and 109 (so far as can be seen the width of the river does not increase downstream), and the Dordrechtsche kil between the kilometrestones 121 and 123. These parts run in nearly straight lines and their depth is not inferior to other parts of these rivers.

This, however, does not prove that a certain winding does not offer some advantage.

Suitable curves afford the advantage that:

1°. at equal depths the width in the curves may be larger,

2°. the channel occupies a fixed position in the bed.

As regards the first case it is advisable when regulating a river to keep the width as great as possible

a) with regard to the discharge of water in times of flood, as the wider a river the greater its increase in area of section with equal rise of the water.

b) with regard to the expense of improvement when, as is usually the case, this consists of a narrowing of the river.

When a curved line of bank is decided upon, the width at the points of inflexion determines the depth in the cross streams.

The determination of this width by calculation should not be impossible, but the calculation should be based on the rate, at which the river is scoured out at the bottom.

This rate depends in a great measure on the nature of the solid matter, which forms the bottom, and is so uncertain, that it would as a rule be better to select parts of the river, where the depth is maintained by action of the current, and to determine, therefrom, which sections are most suitable for the system of the river.

Whithin certain limits, a greater width may then be allowed in the curves.

The measure of this increase must in any case bear relation to the curve, but to ascertain the proportion between these factors will only be possible when more data on the subject are at our disposal than we have at present.

4°. The line followed by the channel in the bed of the rivers shows that the channel has a tendency to wind.

The windings are sometimes remarkably regular, and appear to be subject to a certain law.

The Upper Merwede, where the width was generally too great, was in this respect characteristic.

In curved rivercourses the tendency to the formation of regular winding lines can have a greater influence on the position of the channel, than has the curve of the bed of the river.

Examples.

Lower Merwede between the kilometrestones 109—118;

Dordrechtsche Kil between the kilometrestones 121—129;

Old Maas between the kilometrestones 121—126 and the Upper and the New Merwede above kilometrestone 113.

This proves that it is desirable that:

1°. the curves should be in agreement with the system of the river, and

2°. the curves should be connected in winding lines.

Sharp curves should always be avoided. They may cause the stream to cross over to the convex bank, from which it returns, by which we have two cross streams instead of one.

Example.

New Merwede between the kilometrestones 111 and 112.

It is, especially on tidal rivers with a strong flow, that sharp curves can have a very unfavourable influence, as generally the flood tide does not follow the same channel as the ebb tide.

We then have two channels separated by a slanting shallow on the bed of the river.

b. Rivers with periodically changing bottom.

The great regularity in the changes of bottom, which, according to the diagrams take place, allows us to foresee the variations, which may be expected in the future.

The quantity of solid matter carried by the current is so considerable, that it is of the greatest importance that it be taken into account in the execution of improvements.

So, for instance, the volume of all the channels and shallows regularly carried downstream in the Upper Merwede amounts to 8 500 000 cub.m. (See Pl. III).

After a lapse of $4^1/_2$ to 5 years the channels are found to be in the place where formerly the shallows were and the shallows have taken the former places of the channels. The total bed of the river has then been displaced about 2500 m.

The stream, therefore, removes to this distance in $4^1/_2$ to 5 years 8 500 000 cub.m., that is about 1 800 000 cub.m. per year.

When a plan of regulation is projected, an examination should be made, as to what alterations of the bed would be most likely to favour the object of the works, and as to those which have a reverse tendency.

The execution of the works should then be arranged in such way, as to favour the first and avoid the latter.

For example, if the projected improvement comprises the alteration of the width by means of dikes, to be constructed in the course of years, the executing of the work should be commenced at parts, where the depths are from a technical and financial point of view most suitable and where the bed has a tendency to deepen.

This manner of working offers a double advantage:

1°. the execution of the work is effected in the most economical way; and

2°. the sand displaced by the deepening of these parts is prevented from being deposited in the bed.

And, then, the remaining channels, having no longer any regular current have a strong tendency to being filled by the sand, which is still coming down from the already confined upper part of the river; consequently the mass to be removed by dredging wil become less.

(Translated by G. I. Rowland).

VI[th] International Inland Navigation Congress.

THE HAGUE, 1894.

Relation between Curves in Rivers and the Depth of Water in their Channel.

THE NEW MEUSE AND WATERWAY FROM ROTTERDAM TO THE SEA.

BY

D. J. STEIJN PARVÉ,

Engineer of the Waterstaat, Rotterdam.

For the consideration of the question here proposed, and to examine whether the rivers of the 6[th] district supply any data for its solution, we have graphically described in the four accompanying plates: the New Meuse above Rotterdam, the Scheur and the Hook of Holland Cutting.

The curve of the main stream at low tide, the average of the greatest and the least depth of water in the navigable channel, which is taken as having a regular width of 100 m., and the average high and low tide readings are here given.

Below Schiedam the river may be considered as regulated throughout its whole length. From Schiedam, where the width is 400 m., the main bed of the river becomes 450 m. below Vlaardingen, 550 m. below Maassluis, 650 m. in the Hook of Holland Cutting, and 700 m. at the end of the jetties running into the sea.

Except opposite Maassluis, where at a sharp bend it was necessary to use about eight groins, the regulation of the channel was effected by means of leading dams.

Below Rotterdam there must be a depth of water sufficient for Atlantic liners, hence the request for a minimum depth of 6.50 m. at low water, and a minimum of 100 metres in width. By correcting and regulating the bank and by dredging the main channel these mea-

surements have already been secured in the whole length of river below Rotterdam.

Above Rotterdam the required depth is less. Here 5 metres above low water suffice. The work of correcting the banks and dredging the channel is not yet commenced, so that both in depth as well as in breadth it is very in irregular.

With regard to the general character of the river, throughout its length it is a tidal river.

There is a mean difference of 1.70 m. between high and low water at the mouth, and of 1.25 m. above Krimpen on the Leck.

The volume of water discharged by the river, which receives about $^2/_9$ of the total quantity brought into the country by the Rhine, is about 400 cubic metres per second during mean summer flow.

The regulated stream is composed of arcs of a circle and of straight stretches. For the part of the river not yet regulated the centre of the main channel has been taken, and is treated as composed of arcs of a circle and of straight stretches.

Between km. CXXXIII and CXXXVIII the points of greatest depth are from 300 to 500 metres below the corresponding greatest curve. These latter are at 400 metres below km. CXXXIII, at 600 metres below km. CXXXIV, and at 150 metres below km. CXXXVI, whilst the corresponding greatest hollows are at 700 metres below km. CXXXIII, at km., CXXXV and at 500 m. below km. CXXXVII.

The distances between the two maximum depths have been found to be about the same in the stretch of river from Rotterdam to Schiedam, as well in the length above km. CXLV as for those below km. CXLVIII.

In the very curved portion of river which sweeps round in front of Rotterdam no direct connection has been found between the maximum bend and depth. It has nevertheless been noticed that in this curved portion of the stream the depth is very considerable.

Between Schiedam and Vlaardingen no correlation between bend and depth is found. Below km. CLI the channel approaches the concave bank, and near km. XLII, where the channel strikes across from the left to the right bank, the depth is very considerable.

Below Vlaardingen the river is of normal character; the channel is where one would expect it to be from the nature of the banks. The waterway has in fact been made regular and uniform from Vlaardingen to the sea, and the face of the banks protected with stone. This part of the river is narrowest between km. CLIX and CLXI, and between km. CLXVI and CLXX, stretches which are straight for some considerable distance: viz. for 1400 metres between km. CLVIII and CLX; for 1500 metres between km. CLXIV and CLXVI; also for 2000 metres between km. CLXVIII and CLXX.

The sharpest curves are below Maassluis between km. CLXI and CLXIII, and are separated by a short stretch where the change in direction takes place. At this point the channel passes abruptly from the left to the right bank, and the resulting shallow is found about 100 metres below the turn in direction.

The greatest depth occurs about 300 metres above km. CLXIII whilst the concave curve of the right bank followed by the channel extends to 500 metres above this kilometre. Consequently the maximum depth of this part of the channel must be sought at 200 metres below the change to the left bank.

Perhaps the deepest part of the channel, which extends for about 100 metres below km. CLXIV, may correspond to the maximum curve below the change, although the sharp curve of the right bank changes 600 or 700 metres above km. CLXIV into a much gentler one.

Under the influence of this gentle curve and the straight bit of channel, the depth diminishes gradually and reaches its minimum between km. CLXIX and km. CLXX. From there it again increases slowly and at km. CLXXII attains its greatest depth. Below the kilometre named, the depth is fairly constant, and the concave right bank has a gradual and regular curve to the sea.

The above considerations may be summarised thus:

1. *Although it cannot be doubted that in certain parts of the New Meuse there does exist a correlation between the curve of the river bed and the depth of the channel both above and below Rotterdam, there are also parts where this correlation does not show itself.*

2. *In certain parts of the river the distances between the maximum curve and the corresponding maximum depth of channel are fairly uniform.*

3. *In the regulated portion of the river below Vlaardingen the longest curves correspond to places of minimum depth.*

4. *The facts which prove that there does exist a correlation between the form of a river and the depth of the channel are on the whole neither sufficiently striking nor sufficiently uniform to allow of fixed rules or laws being deduced from them.*

Rotterdam, April 1894.

Inscriptions des Planches.

Boven-Rijn.
Rivière du Waal.
Crue maxima.
Cote des plus basses eaux.
Echelle des largeurs.
Largeur du lit moyen.
Pente kilométrique.
Cote des eaux moyennes.
Cote normale des eaux-basses.

Profondeur du chenal
Profondeur moyenne.
Profondeur maxima.
Ligne du zéro.
Numéros des bornes kilométriques.

Confluent du Maas.
Courbures des rives normales du lit.
La largeur du lit moyen est mésurée entre les rives à la cote des eaux moyennes. Là où des travaux d'art ont régularisé la largeur du lit, cette largeur n'est comptée que de la tête de de l'épi.

Le chenal est censé d'avoir une largeur constante de 150 mètres pour le Boven-Rijn et de 100 mètres pour le Waal. La profondeur portée comme „profondeur du chenal" est la profondeur minima de cette largeur, la profondeur portée comme „profondeur maxima" est la profondeur maxima du chenal.

CASTENDIJK.

Inschriften der Zeichnungen.

Ober-Rhein.
Die Waal.
Maximalhochwasser.
Niedrigste Wasserstände.
Maasstab der Breiten.
Breite des Mittelwasserbettes.
Kilometrisches Gefälle.
Mittelwasserstand.
Normaler Niedrigwasserstand.

Tiefe der Fahrrinne.
Mittlere Tiefe.
Maximaltiefe.
Nulllinie.
Kilometerzahl.

Einfluss der Maas.
Krümmungen der regulirten Ufer.
Die Breite des Mittelwasserbettes ist zwischen den Ufern bei mittlerem Wasserstande gemessen. Wo Kunstbauten die Strombreite regulirt haben, ist die Breite zwischen den Buhnenköpfen gemessen.

Die Breite der Fahrrinne ist für den Ober-Rhein auf eine beständige Breite von 150 m. und für die Waal auf eine solche von 100 m. veranschlagt.
Die als „Fahrwassertiefe" („Profondeur du chenal") eingetragene Tiefe ist die Minimaltiefe in dieser Breite; die als Maximaltiefe eingetragene Tiefe ist die Maximaltiefe in der Fahrrinne.

Description of Plates.

Upper Rine.
River Waal.
Maximum high water.
Comparative level of low water.
Scale of variations in width.
Width of mean bed.
Incline per kilometre.
Comparative mean water-level.
Comparative normal level of low water.
Depth of the channel.
Average depth.
Maximum depth.
Zero line.
Number of kilometres. (Cf. „milestones").
Confluence of the Meuse.
Curves in the bed of normal rivers.
The width of the mean bed is measured between the banks at the comparative mean water-level.
Where constructive works have regulated the with of the bed this width is counted from the heads of the groins.
The channel is supposed to have a constant width of 150 m. on the Upper Rhine and 100 m. on the Waal. The depth styled „maximum depth" is the maximum depth of the channel.

Là où des profondeurs plus considérables se trouvent en dehors du chenal de navigation, ces profondeurs sont indiquées par des lignes brisées.

Quand la rive droite est concave, la courbure $\frac{1}{r}$ est portée au-dessus de la ligne du Zéro; quand la rive gauche est concave, cette courbure est portée au-dessous de la ligne.

Les hachures indiquent sur quelle étendue les bords du lit moyen sont régularisés par des travaux d'art (épis). Travaux de défense de la rive droite , rive gauche .

Le Waal près de St.-Andries.

Déversoir.

Fort.

Ancien Fort.

Fours à briques.

Profondeur de plus de 30 décimètres à la cote indiquée ci-contre.

Banc de sable.

Les nombres indiquent la profondeur du chenal en décimètres à la cote de . . . . .

Nouvelle digue.

Ecluse.

Direction désirée du chenal.

Da, wo sich bedeutendere Tiefen ausserhalb der Fahrrinne vorfinden, hat man dieselben in gebrochenen Linien dargestellt.

Wo das rechte Ufer concav ist, hat man die Krümmung $\frac{1}{r}$ oberhalb der Nulllinie eingeschrieben; wo das linke Ufer concav ist, ist die Krümmung unterhalb der Nulllinie eingetragen.

Die Schraffirungen zeigen an, auf welche Ausdehnung das Mittelwasserbett durch Kunstwerke (Buhnen) regulirt ist. Sicherungsbauten am rechten Ufer , am linken Ufer .

Die Waal bei St. Andries.

Wehr.

Feste.

Ehemalige Feste.

Ziegelöfen.

Tiefe von mehr als 30 Decimeter nach nebenstehendem Wasserstande.

Sandbank.

Die Zahlen zeigen die Tiefe der Fahrrinne in Decimetern nach dem Wasserstande von . . . . an.

Neuer Damm.

Schleuse.

Gewünschte Richtung der Fahrrinne.

When places of more considerable depth are found out-side the channel of navigation, they are indicated by broken lines.

When the right bank is concave the curve $\frac{1}{r}$ is carried above the zero line; when the left bank is concave this curve is carried below the line.

The cross-hatching indicates over what extent the limits of the mean bed are regulated by constructive works (groins). Works for the protection of the right bank , the left bank .

The Waal near St. Andries.

Waste-weir.

Fort.

Old Fort.

Brick-works

Depth of more than 30 decimetres at the comparative level indicated on the opposite page.

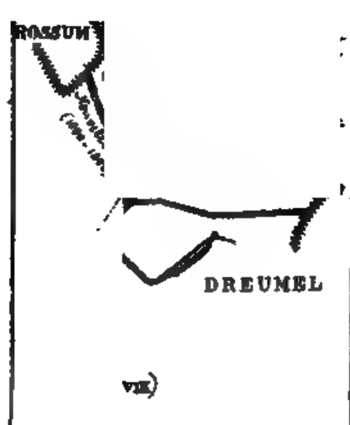
Sandbank.

The figures indicate the depth of the channel in decimetres at the comparative level of . . . . .

New dam.

Sluice.

Requisite direction of the channel.


ROSSUM
DREUMEL

Inscriptions des Planches.

Numéro des bornes kilométriques.

Echelle des courbures.
„ „ largeurs.
„ profondeurs.
Pente kilométrique.
Cote des eaux moyennes.
Courbure de l'axe.
Plan de flottaison normal à la cote de 1.50 m. à l'échelle de Cologne.

Profondeur voulue, 1.70 m. au-dessous du plan de flottaison normal.

Légende.

La largeur du lit mineur est mesurée entre les berges à la cote des eaux moyennes.

Là où des travaux d'art ont régularisé la largeur du lit mineur, cette largeur n'est comptée que de la tête des épis.

La profondeur du chenal est la profondeur minimum dans un chenal, large au moins de 15 m., d'après les sondages d'août 1893.

Quand la rive droite est concave, la courbure (l'inverse du rayon de courbure) de l'axe de la rivière est portée au-dessus de la ligne de zéro.

Quand la rive gauche est concave, la courbure est portée au-dessous de la ligne de zéro.

Description of the Plates.

Number of kilometres (Cf. „Milestones").

Scale of curves.
„ „ widths.
„ „ depths.
Incline per kilometre.
Average height of water.
Bend of the course.
Projection of normal waterline, 1.50 m. after the scale of Cologne.

Requisite depth, 1.70 below the normal water-line.

References.

The width of the summer bed is mesured between the sloping banks at the height of the average water level.

Where constructive works have regulated the width of the summer bed this width is only taken from the heads of the groins.

The depth of the channel is the minimum depth in a channel, at least 15 m. wide, according to the soundings of August, 1893.

When the right bank is concave, the curve (the inverse of the radius of the curve) of the river is carried above the zero line.

When the left bank is concave, the curve is carried below the zero line.

Inschriften der Zeichnungen.

Kilometersteine.

Maasstab der Krümmungen.
„ „ Breiten.
„ „ Tiefen.
Gefälle f. d. Kilometer.
Mittlerer Wasserstand.
Krümmung der Flussachse.
Gemittelter niedrigster Wasserstand bei 1.50 m. am Kölner Pegel.

Gewünschte Fahrwassertiefe, 1.70 m. beim gemittelten niedrigsten Wasserstande.

Erläuterung.

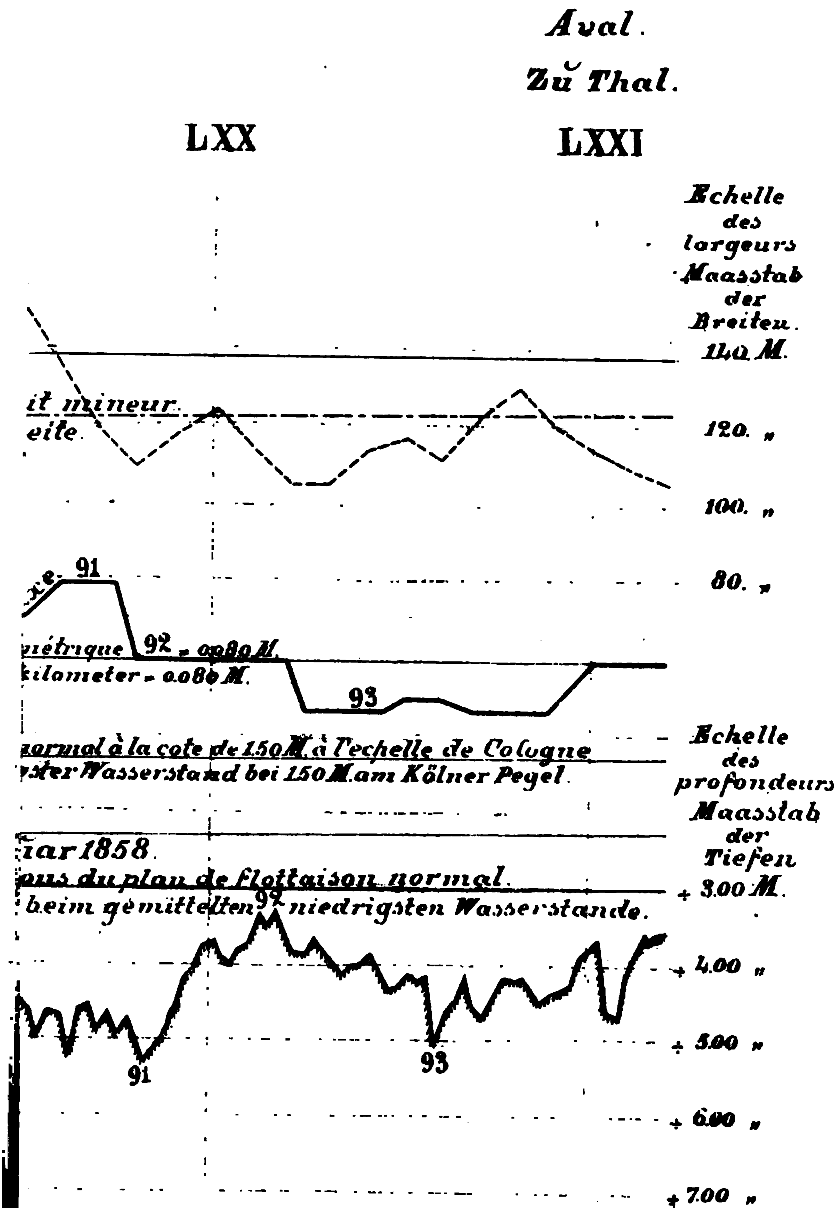
Die Flussbreite ist gemessen zwischen den Ufern beim mittleren Wasserstande.

Wo die Flussbreite durch Buhnen und dergleichen eingeschränkt ist, ist sie von den Köpfen der Einbauten ab gerechnet.

Die Fahrwassertiefe ist die kleinste im August 1893 vorgefundene Tiefe einer Fahrrinne von wenigstens 15 m. Breite.

Die Krümmung (das Umgekehrte des Krümmungshalbmessers) der Flussachse ist, falls das rechte Ufer hohl ist, als positiver, falls das linke Ufer hohl ist, als negativer Werth eingetragen.

Inscriptions souvent répétées.	*Words frequently repeated.*	*Oft wiederholte Inschrift*
En amont.	**Up stream.**	**Stromaufwärts.**
En aval.	**Down stream.**	**Stromabwärts.**
Crue.	**Flood.**	**Hochwasser.**
Pente.	**Incline.**	**Gefälle.**
Etiage.	**Low water.**	**Niedrigwasser.**
Cote des eaux.	**Comparative height of water.**	**Wasserstand.**
Contours.	**Outline.**	**Krümmungen.**
Près du village	**Near the village . . . .**	**Bei dem Dorfe . . . .**



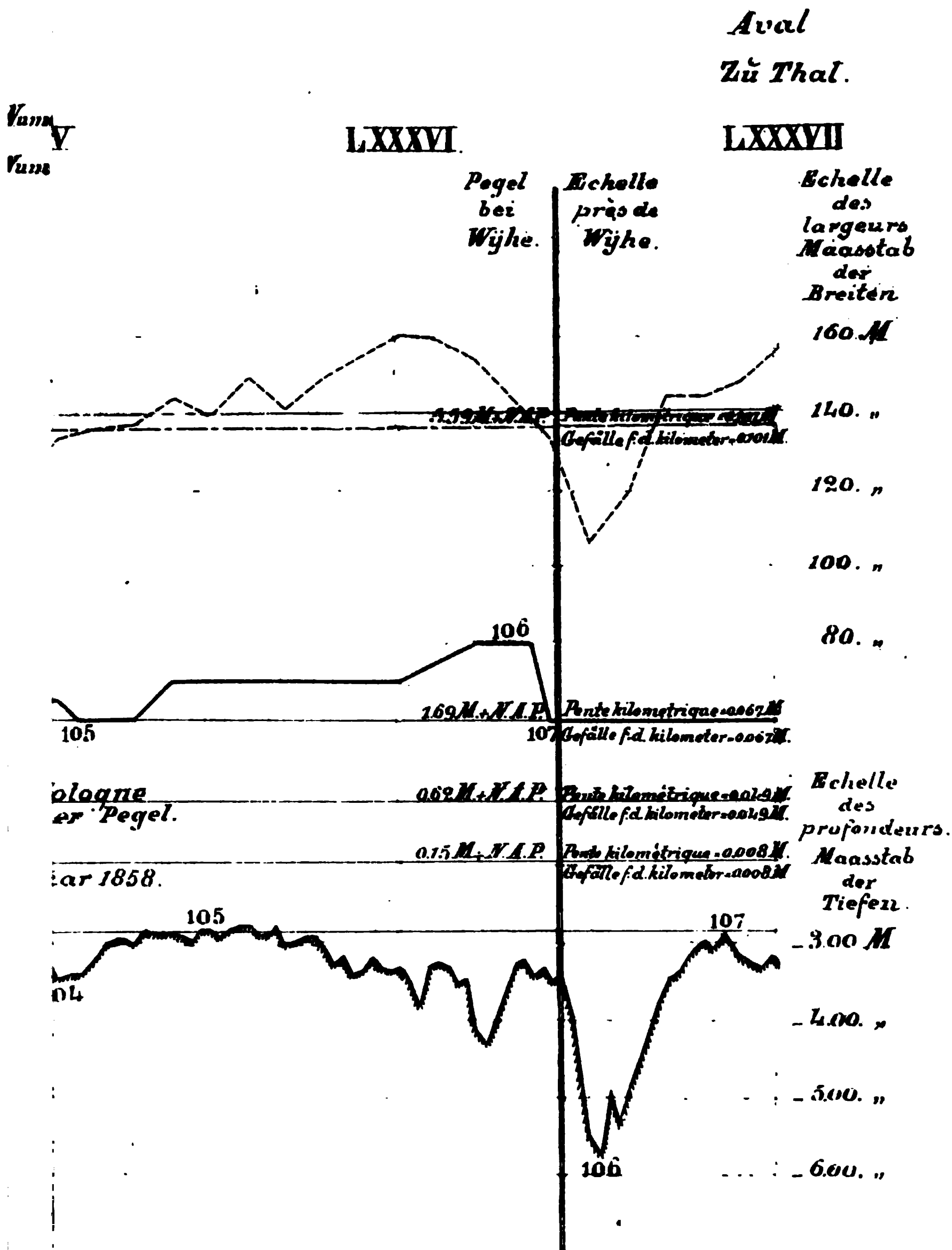
Erläuterung

Die Flussbreite ist gemessen zwischen den Ufern beim mittleren Wasserstande.

Wo die Flussbreite durch Bühnen und dergleichen eingeschränkt ist, ist sie von den Köpfen der Einbauten ab gerechnet.

Die Fahrwassertiefe ist die kleinste im August 1893 vorgefundene Tiefe einer Fahrrinne von wenigstens 15 M Breite.

Die Krümmung (das Umgekehrte der Krümmungshalbmessers) der Flussachse ist, falls das rechte Ufer hohl ist, als positiver; falls das linke Ufer hohl ist, als negativer Werth eingetragen.



Erläuterung.

Die Flussbreite ist gemessen zwischen den Ufern beim mittleren
werstande.

Wo die Flussbreite durch Bühnen und dergleichen eingeschränkt
ist sie von den Köpfen der Einbauten ab gerechnet.

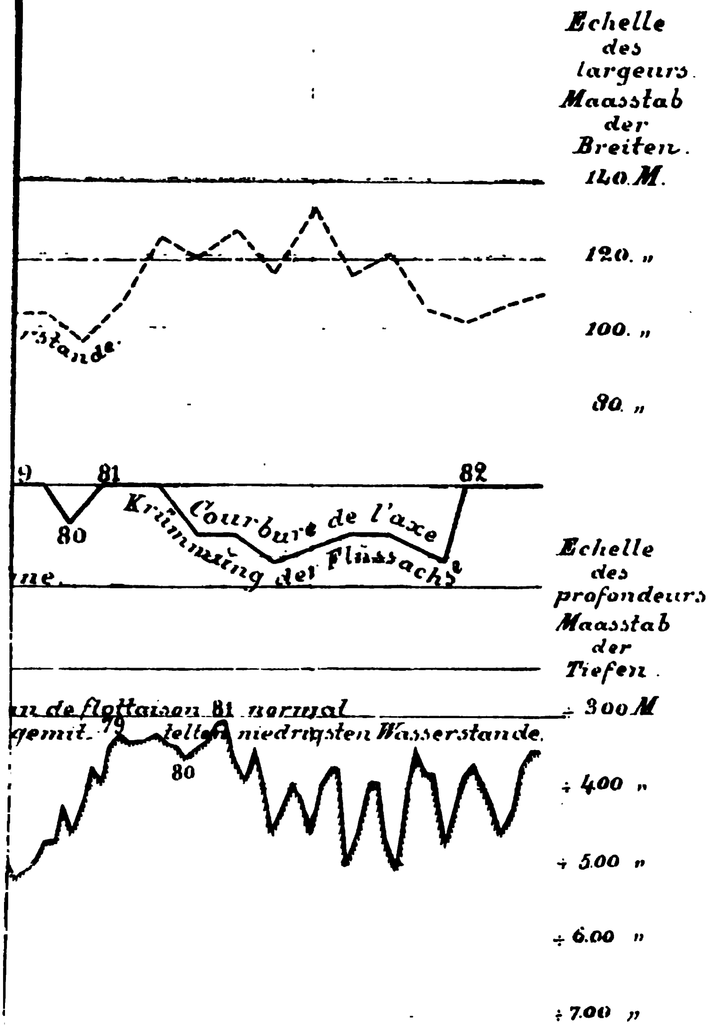
Die Fahrwassertiefe ist die kleinste im August 1893 vorgefundene
e einer Fahrrinne von wenigsten 15 M. Breite.

Die Krümmung (das Umgekehrte des Krümmungshalbmessers
Flussachse ist, falls das rechte Ufer hohl ist, als positiver; falls
linke Ufer hohl ist, als negativer Werth eingetragen.

Photolith. procédé Mr. E. J. Asser. Steendr. v/h. Amand, Amst.

Aval.
Zu Thal.

LXIV



Erläuterung.

Die Flussbreite ist gemessen zwischen den Ufern beim mittleren Wasserstande.

Wo die Flussbreite durch Buhnen und dergleichen eingeschränkt ist, ist sie von den Köpfen der Einbauten ab gerechnet.

Die Fahrwassertiefe ist die kleinste im August 1893 vorgefundene Tiefe einer Fahrrinne von wenigstens 15 M. Breite.

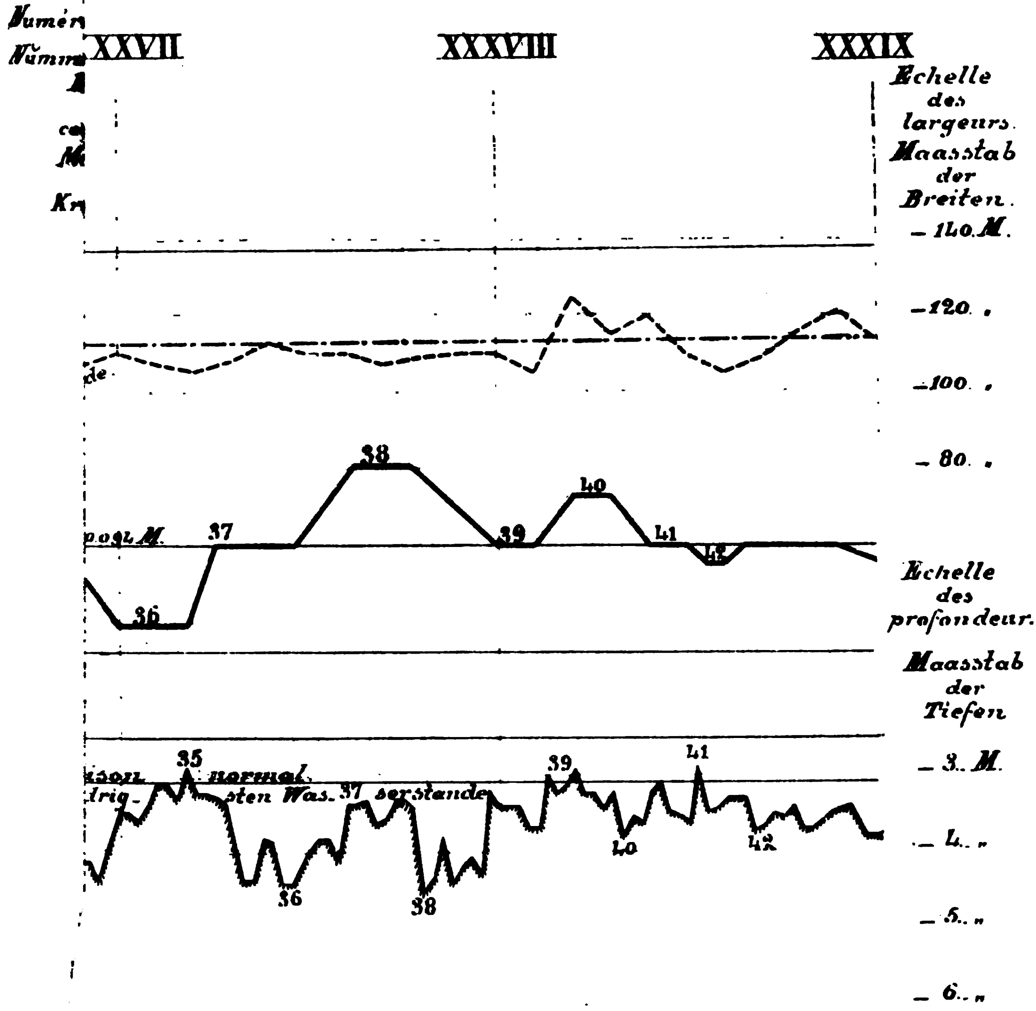
Die Krümmung (das Umgekehrte des Krümmungshalbmessers) der Flussachse ist, falls das rechte Ufer hohl ist, als positiver; falls das linke Ufer hohl ist, als negativer Werth eingetragen.


Pegel
bei
7.7
13
XX

men.

nen.

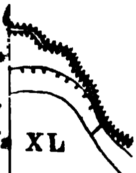
Aval
Zu Thal.



Limen.

Erläuterung

La
berges
La,
lit mi
La
un ch
Qu
rayon
de la
Qu
au. d

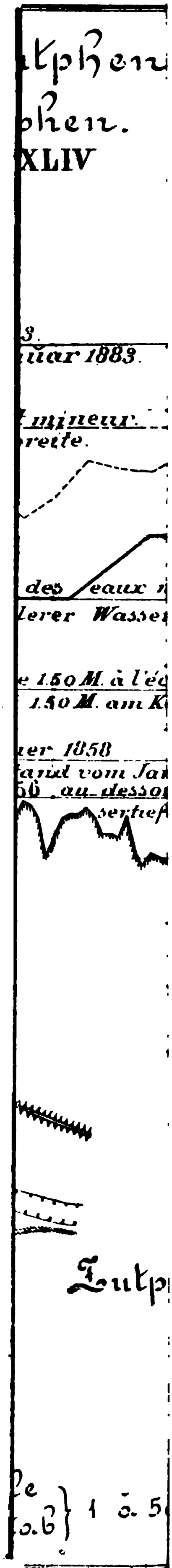


Die Flussbreite ist gemessen zwischen den Ufern beim mittleren Wasserstande.

Wo die Flussbreite durch Buhnen und dergleichen eingeschränkt ist, ist sie von den Köpfen der Einbauten abgerechnet.

Die Fahrwassertiefe ist die kleinste im August 1893 vorgefundene Tiefe einer Fahrrinne von wenigstens 15 M. Breite.

Die Krümmung (das Umgekehrte des Krümmungshalbmessers) der Flussachse ist, falls das rechte Ufer hohl ist, als positiver; falls das linke Ufer hohl ist, als negativer Wert eingetragen.



tphen
phen.
XLIV
uar 1883.
mineur.
reite.
des eaux
lerer Wasse
e 1.50 M. à l'é
1.50 M. am K
er 1858
and vom Ja
56 . au-desso
sertief

Inscriptions des Planches.

Rhin Inférieur.

Numéro des bornes.

Cote des eaux moyennes.

Courbure de l'axe du lit mineur.

La largeur du lit mineur est mesurée entre les berges à la cote moyenne des eaux. Là où des travaux d'art ont régularisé la largeur du lit mineur, cette largeur n'est comptée que de la tête de l'épi.

Le chenal est censé d'avoir une largeur constante de 50 m., la profondeur portée comme „profondeur du chenal" est la profondeur minima de cette largeur; la „profondeur maxima" est la profondeur maxima du chenal.

Là où des profondeurs plus considérables se trouvent en dehors du chenal de navigation, ces profondeurs sont indiquées par des lignes brisées — — — — —

Quand la rive droite est concave la courbure $\left(\frac{1}{r}\right)$ est portée au-dessus de la ligne de zéro; quand la rive gauche est concave, cette courbure est portée au-dessous de la ligne.

La ligne rouge — — — — — indique la largeur après l'achèvement

Description of the Plates.

Lower Rhine.

Number of kilometres (Cf. „Milestones").

Average comparative height of the water.

Curve in the summer bed.

The width of the summer bed is measured between the sloping banks at the average comparative height of the water. Where constructive works have regulated the summer bed, this width is only counted from the heads of the groins.

The channel is considered to have a constant width of 50 m.; the depth styled the „depth of the channel" is the minimum depth at this width; the „maximum depth" is the maximum depth of the channel.

Where regions of greater depth are met with outside the channel of navigation, they are indicated by dotted lines — — — — —

When the right bank is concave the curve $\left(\frac{1}{r}\right)$ is carried above the zero line; when the left bank is concave, this curve is carried below the line.

The red line — — — — — indicates the width after the completion

Inschriften der Zeichnungen.

Nieder-Rhein.

Kilometer.

Mittelwasser.

Krümmung des Flussbettes (genau: Krümmung der Achse des Sommerbettes).

Die Breite des Flussbettes wird gemessen zwischen den Ufern auf der Höhe des Mittelwassers.

Wo die Breite mit Buhnen regulirt ist, wird dieselbe gemessen zwischen den Linien, welche die Köpfe der Buhnen verbinden.

Die Breite der Fahrrinne ist zu 50 m. angenommen. „Tiefe der Fahrrinne" bezeichnet die Minimaltiefe in dieser Breite. „Maximaltiefe" ist die grösste Tiefe in dieser Breite.

Wo sich grössere Tiefen ausserhalb der Fahrrinne befinden, sind diese mit gebrochenen Linien — — — — bezeichnet.

Bei konkaven rechten Ufern wird die Krümmung $\left(\frac{1}{r}\right)$ oberhalb der Nullinie ausgesetzt, bei konkaven linken Ufern unterhalb der Nullinie.

Die Linie rothe — — — — — bezeichnet die Breite nach Beendigung

des travaux de régulation en exécution.

Les hachures indiquent sur quelles étendues les bords du lit mineur seront régularisés après l'exécution de ces travaux d'art. Travaux de défense de la rive droite , rive gauche .

of the regulating works at present in course of construction.

The cross-hatching indicates over what extent the limits of the summer bed will be regulated after the completion of these constructive works. Works for the protection of the right bank ,left bank .

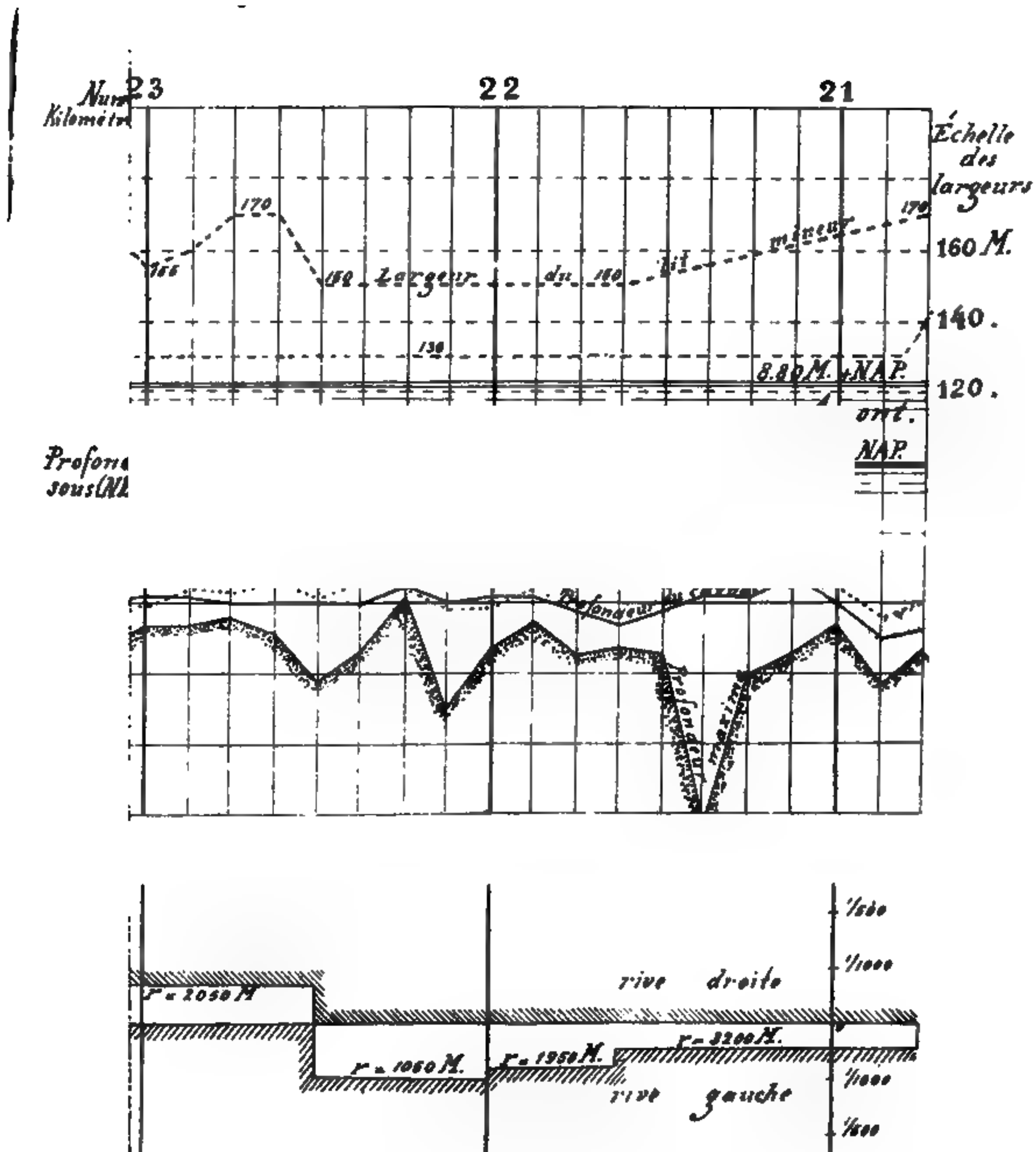
der angefangenen Regulirungsbauten.

Die Schraffirungen weisen an, wo das Flusbett durch Kunstwerke regulirt ist.

Kunstwerke am rechten Ufer .

Kunstwerke am linken Ufer .

Inscriptions souvent répétées.	*Words frequently repeated.*	*Wiederholt vorkommende Ausdrücke.*
Echelle.	Scale.	Maasstab.
Crue.	Flood.	Hochwasser.
Pente.	Incline.	Gefälle.
Cote des eaux.	Comparative height of water.	Wasserstand.
En amont.	Up stream.	Stromauf.
En aval.	Down stream.	Stromab.
Rive.	Bank.	Ufer.



Quand la rive droite est concave
courbure ($\frac{1}{r}$) est portée au-dessus
la ligne du zéro; quand la rive
uche est concave, cette courbure
portée au-dessous de la ligne.
La ligne rouge----indique la
rgeur après l'achèvement des
avaux de régulation en exécution.
Les hachures indiquent sur quelle
endue les bords du lit mineur
ront régularisés après l'exécution
ces travaux d'art. Travaux de
fense de la rive droite rive
uche

Inscriptions des Planches.

PLANCHE I.

Beneden-Merwede.

Courbe des courbures.

Largeurs du lit mineur.

Position du chenal dans le lit mineur.

Profondeurs maxima du chenal continu.

Aires des sections transversales au-dessous mi-marée.

Hautes et basses-mers ordinaires.

Longueur.

Pour la Beneden-Merwede, on a pris les profondeurs et les aires des sections moyens pendant les années 1886—1893.

PLANCHE II.

Nieuwe Merwede.

Boven „

Profondeurs minima sur les hauts-fonds.

Plan de comparaison du zéro d'Amsterdam.

Partie du chenal située le long de la rive gauche.

Rive droite.

(Pour les autres expressions, voir les traductions „Planche I".)

PLANCHE III.

Cartes des profondeurs de la Boven Merwede montrant des variations du fond.

Hauts fonds s'élevant au-dessus de AP.

Lignes des profondeurs de 2 m. au-dessous de AP.

Chenals de plus de 4 m. de profondeur au-dessous de AP.

Inschriften der Zeichnungen.

BLATT I.

Unter-Merwede.

Krümmungslinien.

Breite des Sommerbettes.

Lage der Fahrrinne im Sommerbette.

Maximaltiefen der fortlaufenden Fahrrinne.

Flächeninhalt der Querschnitte unter halber Fluthhöhe.

Gewöhnlicher Stand von Ebbe und Fluth.

Länge.

Für die Unter-Merwede hat man die mittleren Tiefen und Querschnittsinhalte der Jahre 1886—1893 angenommen.

BLATT II.

Neue Merwede.

Ober „

Mindesttiefen an den flachen Stellen.

Vergleich mit 0 am Amsterdamer Pegel.

Längs dem linken Ufer gelegener Theil der Fahrrinne.

Rechtes Ufer.

(Die übrigen Ausdrücke siehe Uebersetzung zu Blatt I.)

BLATT III.

Tiefendarstellungen der Ober-Merwede, welche Bodenveränderungen zeigen.

Untiefen, welche sich über AP. (Amsterdamer Pegel) erheben.

Tiefen von 2 m. unter AP.

Furchen von mehr als 4 m. Tiefe unter AP.

Description of the Plates.

PLATE I.

Lower Merwede.

Curve.

Width of the summer bed.

Position of the channel in the summer bed.

Maximum depth of the continuous channel.

Area of transverse sections below half-tide.

Ordinary high and low water.

Length.

The depths and average areas of sections on the Lower Merwede have been taken during the years 1886—1893.

PLATE II.

New Merwede.

Upper „

Minimum depths on the shoals.

Comparative projection after the standard of Amsterdam.

Part of the channel situated along the left bank.

Right bank.

(For other expressions see translations under Plate I.)

PLATE III.

Chart of depths of the Upper Merwede showing variations in the bottom.

Shoals rising above AP. (The standard of Amsterdam.)

Depth of 2 m. above AP.

Channels more than 4 m. deep below AP.

Schuurman & van Hooff.

PLANCHE IV.

Diagrammes montrant les volumes et les déplacements des chenals et des hauts-fonds de la Boven Merwede.

Les chenals sont pris au-dessous d'un plan s'abaissant de 2 m. — AP. à la bouche d'amont à 3 m. — AP. à la bouche d'aval; les hauts-fonds au-dessus du même plan.

La surface de la courbe des aires des sections représent le volume du chenal ou du haut-fond.

Le nombre inscrit donne le volume en 1000iers de mètres-cubes.

(Pour les autres expressions, voir les traductions „Planche I".)

BLATT IV.

Diagramme zur Darstellung der Volumen und der Verschiebungen der Rinnen und Untiefen.

Die Rinnen sind unter einem Wasserstande liegend berechnet, der von 2 — AP. an der oberen Mündung auf 3 m. — AP. an der unteren Mündung fällt; die Untiefen oberhalb dieses Wasserstandes liegend.

Die Oberfläche der Querschnittsinhalte stellt das Volumen der Rinne oder der Untiefe dar.

Die eingeschriebenen Ziffern beziehen sich auf das Volumen in tausendstel Kubikmetern.

(Die übrigen Ausdrücke siehe Uebersetzung zu Blatt I.)

PLATE IV.

Diagrams showing the volumes and the movement of channels and shoals of the Upper Merwede.

The channels are taken below a height of from 2 m. below AP. at the upper mouth to 3 m. below AP. at the lower mouth; the shoals above the same level.

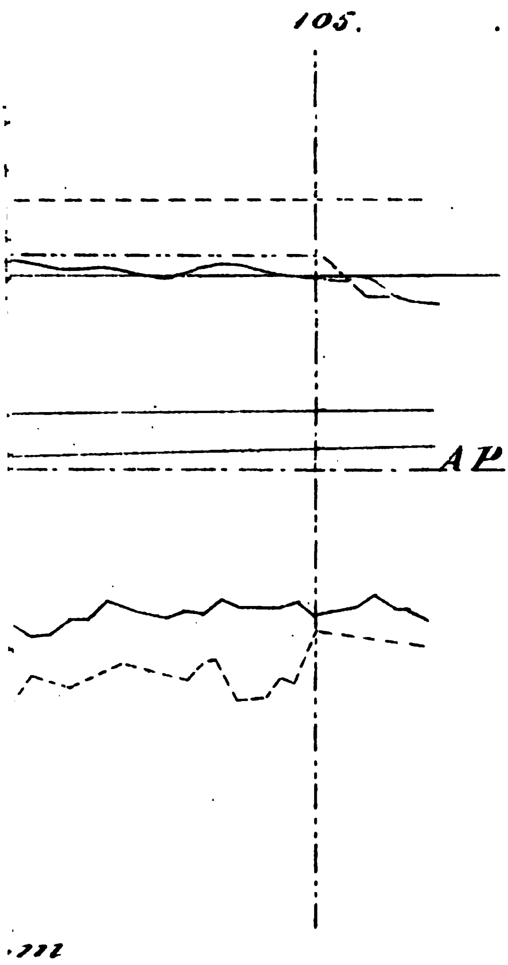
The surface of the curve of the areas of the sections represent the volume of the channel or of the shoal.

The number inscribed gives the volume in thousands of cubic metres.

(For other expressions see translations under Plate I.)

Planche N° I.

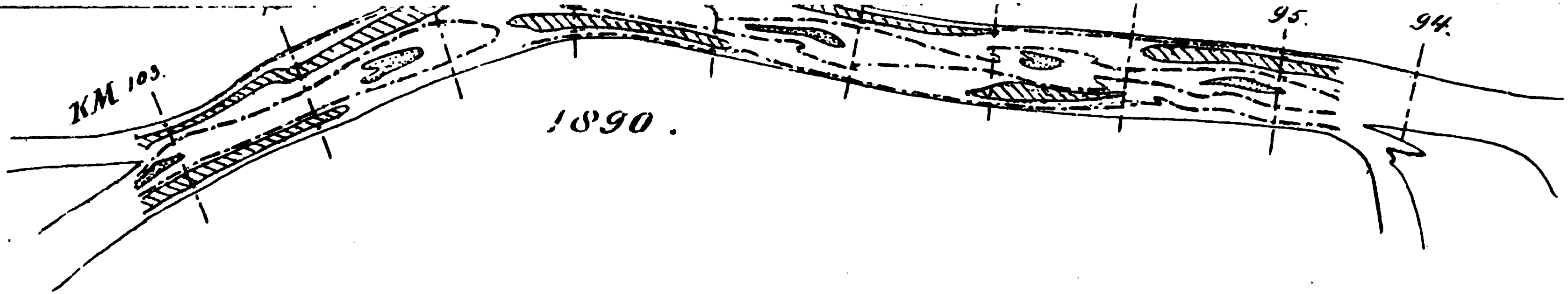
r·wede.



·m

à pris les profondeurs
ndant les années 1886-1893.


A.P.
B.M.
1000
4
5



Hauts fonds s'élevant audessus de AP.

Ligne des profondeurs de 2 m au dessous de AP.

Chenals de plus de 4 m de profondeur au dessous de AP.

Echelle 1 cm = 500 m.

Les chenals sont pris au dessous d'un plan s'abaissant de 2 m-AP à la bouche d'amont à 3 m-AP à la bouche d'aval; les hauts-fonds au dessus du même plan.

Echelles.

1. Courbe des aires des sections des chenals le long de la rive droite. $1\,mm = 100\,m^2$

2. Courbes des aires des sections des hauts-fonds . . . . . $1\,mm = 100\,m^2$.

3. Courbe des aires des sections des chenal le long de la rive gauche . $1\,mm = 100\,m^2$.

Echelles des longueurs . . . . . . $1\,cm = 500\,m$.

La surface de la courbe des aires des sections represent le volume du chenal ou du haut-fond . . . . . . $1\,mm^2 = 5000\,m^3$

Le nombre inscrit donne la volume en 1000 iers de metres cubes

STEENDRUKKERIJ v/h. AMAND, Amst.

Inscriptions des Planches.

Nouvelle Meuse et Voie d'eau de Rotterdam à la mer.

FEUILLE I.

Numéros des bornes kilométriques.

Echelle.
Marée maxima.
Echelle des largeurs.
Aval.
Amont.
Cote des marées hautes moyennes.

Cote des marées basses moyennes.

Largeur du lit.
Profondeur moyenne.
Profondeur du chenal.
Profondeur maxima.
Courbure de l'axe du lit.

Rive droite.
Rive gauche.
Ligne du zéro.

La largeur du lit est mesurée entre les berges à la hauteur des marées basses moyennes. Là où des travaux d'art ont régularisé la largeur du lit, cette largeur n'est comptée que de la tête des épis.

Le chenal est censé d'avoir une largeur constante de 100 mètres La profondeur portée comme „profondeur du chenal" est la profondeur minima de cette largeur, la profondeur portée comme „profondeur maxima" est la profondeur maxima du chenal.

Steyn Parvé.

Inschriften der Zeichnungen.

Neue Maas und Wasserweg von Rotterdam zum Meere.

BLATT I.

Kilometerzahl.

Maasstab.
Höchster Stand der Fluth.
Maasstab der Breiten.
Stromab.
Stromauf.
Mittlerer hoher Fluthstand.

Mittlerer niedriger Fluthstand.

Breite des Strombettes.
Mittlere Tiefe.
Tiefe der Fahrrinne.
Maximaltiefen.
Krümmung der Achse des Strombettes.
Rechtes Ufer.
Linkes Ufer.
Nullinie.

Die Breite des Strombettes ist zwischen den Ufern in der Höhe des mittleren niedrigen Fluthstandes gemessen. Da, wo dass Bett durch Kunstbauten regulirt ist, hat man die Breite zwischen den Buhnenköpfen gemessen.

Man hat für die Fahrrinne eine beständige Breite von 100 m. angenommen. Die als Fahrrinnentiefe („profondeur du chenal") eingetragene Tiefe ist die kleinste in dieser Breite vorhandene; die als Maximaltiefe („profondeur maxima") eingetragene Tiefe ist die Maximaltiefe der Fahrrinne.

Description of the Plates.

New Meuse and Water-way from Rotterdam to the sea.

PLATE I.

Number of kilometres (Cf. „Milestones").
Scale.
High water mark.
Scale of width.
Down stream.
Up stream.
Comparitive height of average high water.
Comparative height of average low water.
Width of the bed.
Average depth.
Depth of the channel.
Maximum depth.
Curve of the bed.

Right bank.
Left „
Zero line.

The width of the bed is measured between the sloping banks at the height of average low water. Where constructive works have regulated the width of the bed, this width is only counted from the head of the groins.

The channel is considered to have a constant width of 100 m. The depth styled the „depth of the channel" is the minimum depth at this width; the depth styled „maximum depth" is the maximum depth of the channel.

Là où des profondeurs plus considérables se trouvent en dehors du chenal de navigation, ces profondeurs sont indiquées par des lignes brisées — — — — —

Quand la rive droite est concave, la courbure $\left(\frac{1}{r}\right)$ est portée au-dessus de la ligne du zéro; quand la rive gauche est concave, cette courbure est portée au-dessous de la ligne.

Les hachures indiquent sur quelle étendue les bords du lit sont régularisés par des travaux d'art (épis). Travaux de défense de la rive droite , rive gauche , défense plus ou moins partielle , .

FEUILLE II, III, IV.

(Voir les traductions sous „Feuille I").

Wo sich ausserhalb der Fahrrinne beträchtlichere Tiefen vorfinden, hat man dieselben durch punktirte Linien — — — — — angegeben.

Wenn das rechte Ufer concav ist, hat man die Krümmung $\left(\frac{1}{r}\right)$ über der Nullinie eingetragen; wenn das linke Ufer concav ist, hat man die Eintragung unter jener Linie vorgenommen.

Die Schraffirungen zeigen an, in welcher Ausdehnung die Ufer durch Kunstbauten (Buhnen) regulirt sind. Kunstbauten am rechten Ufer , am linken Ufer , mehr oder weniger theilweise Sicherungen , .

BLATT II, III, IV.

(Siehe Uebersetzung zu Blatt I).

Where regions of greater depth are met with outside the channel of navigation, they are indicated by dotted lines — — — — —

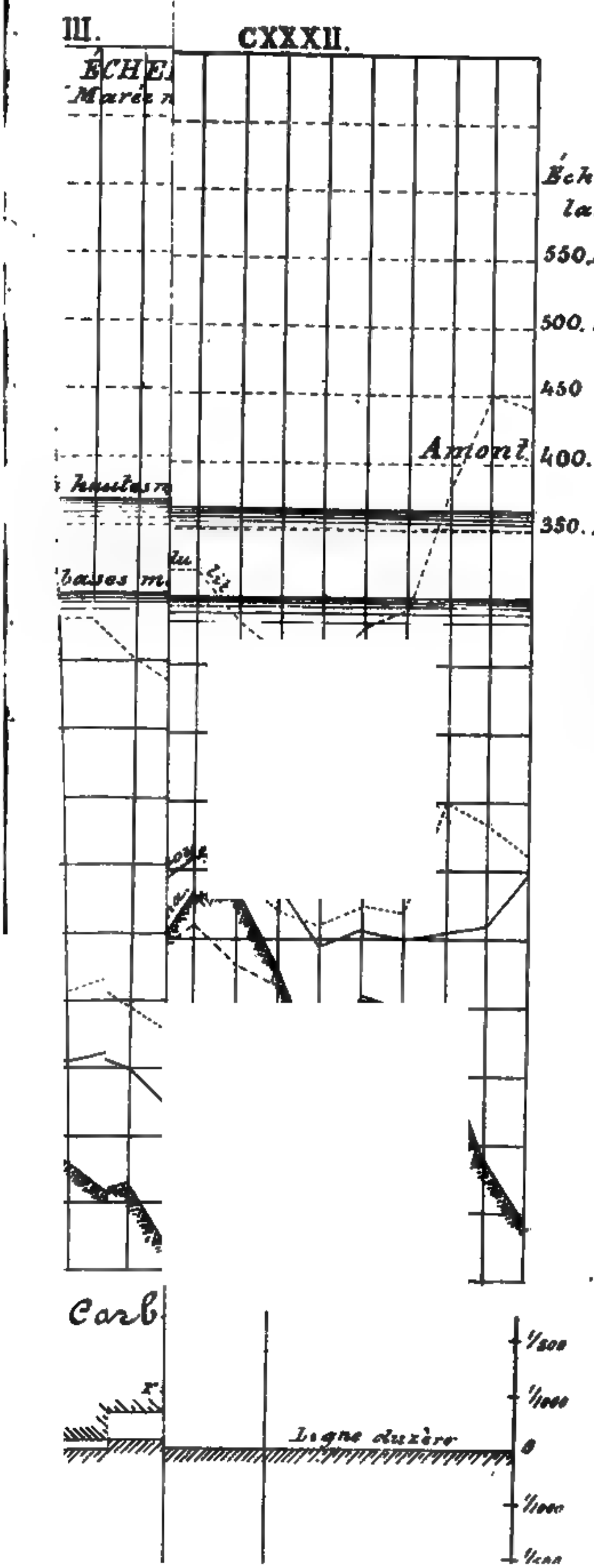
Where the right bank is concave the curve $\left(\frac{1}{r}\right)$ is carried above the zero line; when the left bank is concave this curve is carried below the line.

The cross-hatching indicates over what extent the limits of the bed are regulated by the constructive works (groins). Works for the protection of the right bank , the left bank , more or less partial protection , .

PLATES II, III, IV.

(See translations under Plate I.).

Planche I.



La largeur du lit est mesurée entre les berges à la hauteur des marées basses moyennes. Là où des travaux d'art ont régularisé la largeur du lit, cette largeur n'est compté que de la tête des épis.

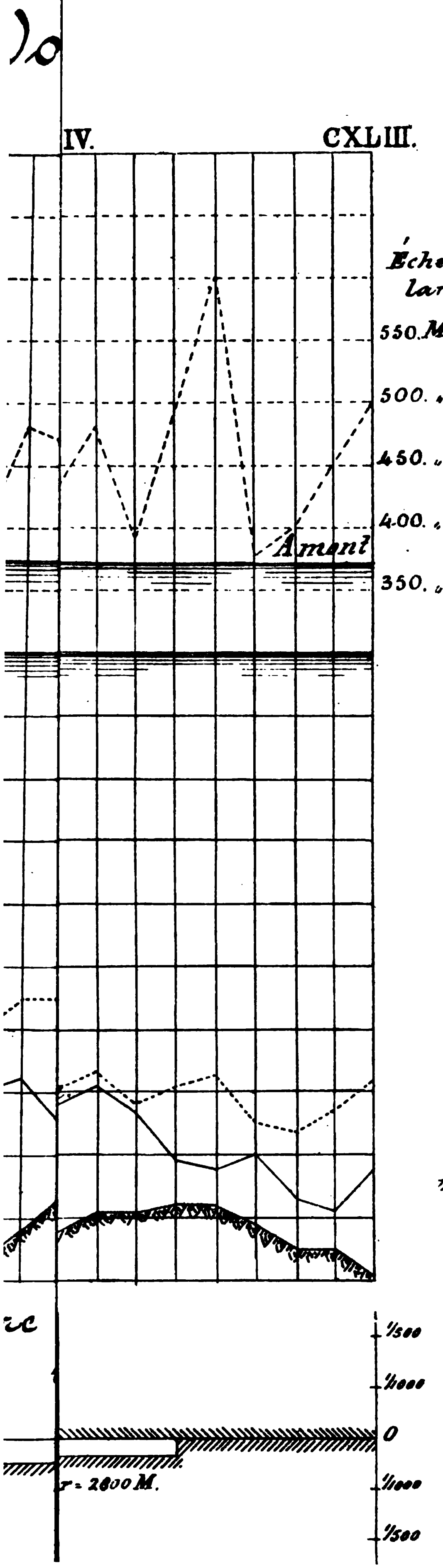
Le chenal est sensé d'avoir une largeur constante de 100 mètres. La profondeur portée comme »profondeur du chenal" est la profondeur minima de cette largeur; la profondeur portée comme »profondeur maxima" est la profondeur maxima du chenal.

Là où des profondeurs plus considérables se trouvent en dehors du chenal de navigation, ces profondeurs sont indiquées par des lignes brisées ....

Quand la rive droite est concave la courbure ($\frac{1}{r}$) est portée au-dessus de la ligne du zéro; quand la rive gauche est concave cette courbure est portée au-dessous de la ligne.

Les hachures indiquent sur quelle étendue les bords du lit sont regularisés par des travaux d'art (épis). Travaux de défense de la rive droite , rive gauche défense plus ou moins partielle

Planche II.



La largeur du lit est mesurée entre les berges à la hauteur des marées basses moyennes. Là où des travaux d'art ont régularisé la largeur du lit, cette largeur n'est compté que de la tête des épis.

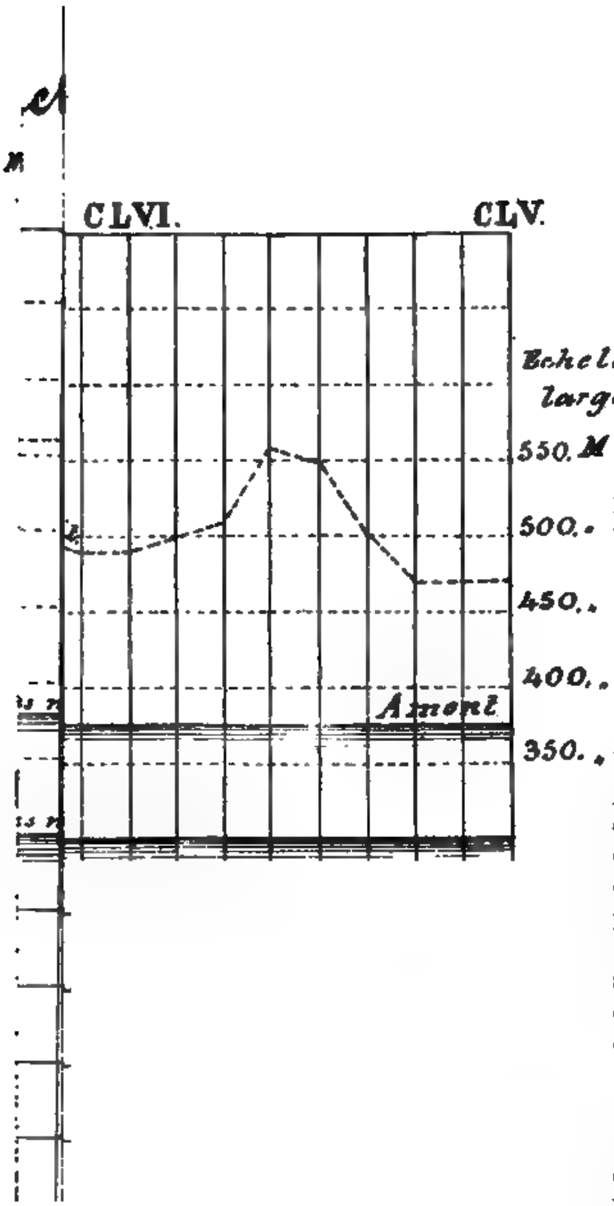
Le chenal est sensé d'avoir une largeur constante de 100 mètres. La profondeur portée comme »profondeur du chenal" est la profondeur minima de cette largeur; la profondeur portée comme »profondeur maxima" est la profondeur maxima du chenal.

Là où des profondeurs plus considérables se trouvent en dehors du chenal de navigation, ces profondeurs sont indiquées par des lignes briséés - - - - - -

Quand la rive droite est concave la courbure $(\frac{1}{r})$ est portée au-dessus de la ligne du zéro; quand la rive gauche est concave cette courbure est portée au-dessous de la ligne.

Les hachures indiquent sur quelle étendue les bords du lit sont regularisés par des travaux d'art (épis). Travaux de défense de la rive droite, rive gauche, défense plus ou moins partielle

Planche III.



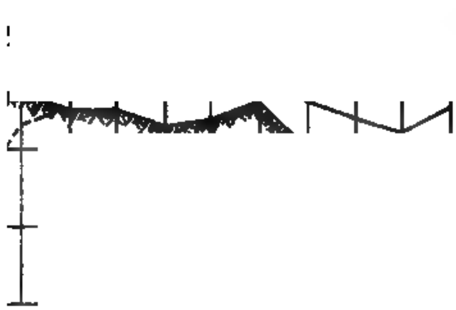
La largeur du lit est mesurée entre les berges à la hauteur des marées basses moyennes. Là où des travaux d'art ont régularisé la largeur du lit, cette largeur n'est compté que de la tête des épis.

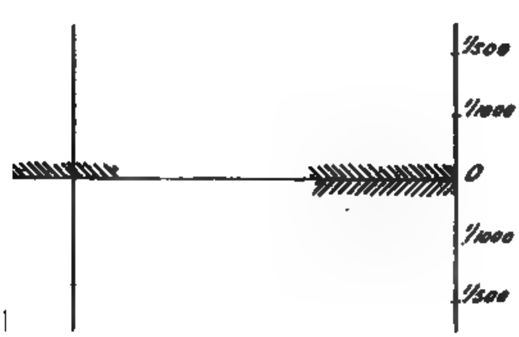
Le chenal est sensé d'avoir une largeur constante de 100 mètres. La profondeur portée comme »profondeur du chenal" est la profondeur minima de cette largeur; la profondeur portée comme »profondeur maxima" est la profondeur maxima du chenal.

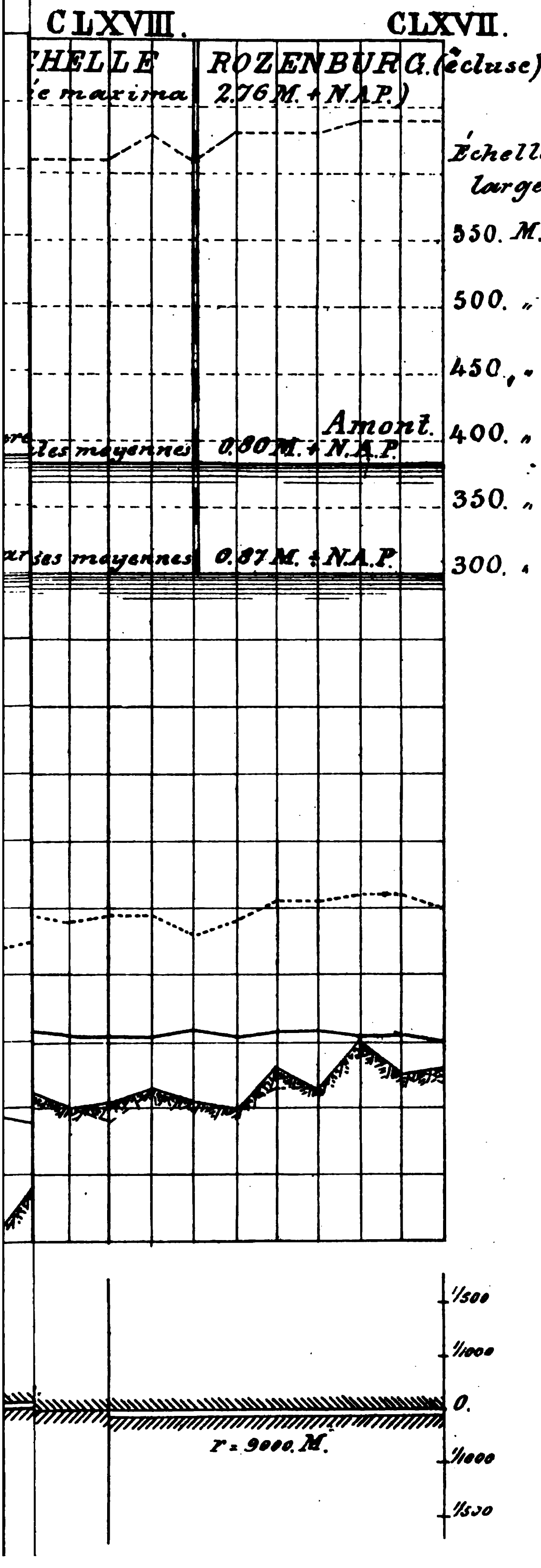
Là où des profondeurs plus considérables se trouvent en dehors du chenal de navigation, ces profondeurs sont indiquées par des lignes briséés - - - - - -

Quand la rive droite est concave la courbure $(\frac{1}{R})$ est portée au-dessus de la ligne du zéro; quand la rive gauche est concave cette courbure est portée au-dessous de la ligne.

Les hachures indiquent sur quelle étendue les bords du lit sont regularisés par des travaux d'art (épis). Travaux de défense de la rive droite, rive gauche défense plus ou moins partielle







La largeur du lit est mesurée entre les berges à la hauteur des marées basses moyennes. Là où des travaux d'art ont régularisé la largeur du lit, cette largeur n'est compté que de la tête des épis.

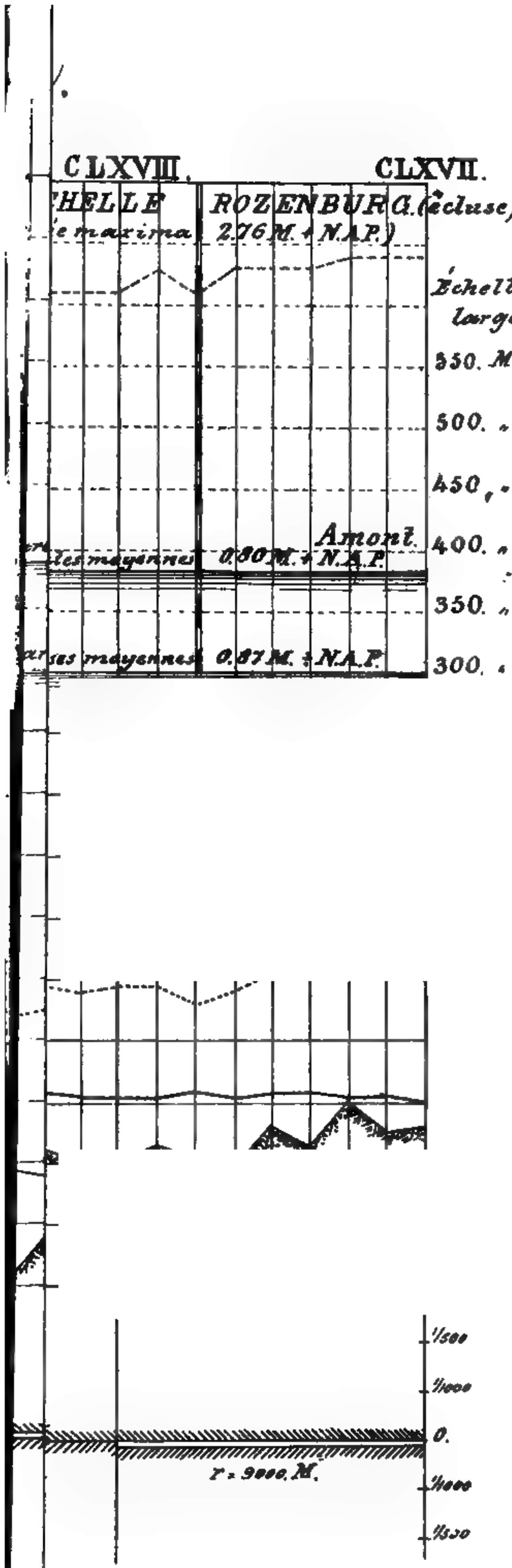
Le chenal est sensé d'avoir une largeur constante de 100 mètres. La profondeur portée comme »profondeur du chenal" est la profondeur minima de cette largeur; la profondeur portée comme »profondeur maxima" est la profondeur maxima du chenal.

Là où des profondeurs plus considérables se trouvent en dehors du chenal de navigation, ces profondeurs sont indiquées par des lignes briséés - - - - - - -

Quand la rive droite est concave la courbure $\left(\frac{1}{r}\right)$ est portée au-dessus de la ligne du zéro; quand la rive gauche est concave cette courbure est portée au-dessous de la ligne.

Les hachures indiquent sur quelle étendue les bords du lit sont regularisés par des travaux d'art (épis). Travaux de défense de la rive droite, rive gauche défense plus ou moins partielle

Planche IV.



La largeur du lit est mesurée entre les berges à la hauteur des marées basses moyennes. Là où des travaux d'art ont régularisé la largeur du lit, cette largeur n'est compté que de la tête des épis.

Le chenal est sensé d'avoir une largeur constante de 100 mètres. La profondeur portée comme »profondeur du chenal" est la profondeur minima de cette largeur; la profondeur portée comme »profondeur maxima" est la profondeur maxima du chenal.

Là où des profondeurs plus considérables se trouvent en dehors du chenal de navigation, ces profondeurs sont indiquées par des lignes brisées - - - - - -

Quand la rive droite est concave la courbure $\left(\frac{1}{R}\right)$ est portée au-dessus de la ligne du zéro; quand la rive gauche est concave cette courbure est portée au-dessous de la ligne.

Les hachures indiquent sur quelle étendue les bords du lit sont regularisés par des travaux d'art (épis). Travaux de défense de la rive droite , rive gauche défense plus ou moins partielle

28

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.

THE HAGUE, 1894.

6th QUESTION.

RIVER CURRENTS

AND THE

Configuration of river beds.

BY

L. LÉLIAVSKI,
Engineer.

THE HAGUE,
Printed by Belinfante Bros, late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

VI[th] International Inland Navigation Congress.

THE HAGUE, 1894.

RIVER CURRENTS AND THE CONFIGURATION OF RIVER BEDS

BY

L. LÉLIAVSKI,

Engineer.

Nothwithstanding the great works of several mathematians, hydrodynamics have not yet given a single exact formula absolutely adoptable to practical combinations. This arises, in our opinion from the fact that the subject of the displacement of fluids in the midst of resistances has not been sufficiently examined in an experimental way; and that in the principles of mathematical deductions there are admissions incompatible with reality. Observations show that there is no one point in a fluvial current where the threads of water have a direction completely parallel, but, as the laws on which the direction of the water-threads depend are unknown and their deviation from a parallel line appears to be accidental, it has been generally admitted for the deduction of hydrodynamic formulae that all water-threads run in parallel directions to one another.

NAVIER, following the hypothesis of NEWTON that interior hydraulic frictions are the lineal sunctions of relative speeds introduced into the equation of the movement of fluids a coefficient of interior friction resulting from the nature of the fluid and of its temperature. BUSSINESK after a few unimportant changes applied these formulae to the straight movement of parallel threads and has drawn conclusions which agree nearly with the results of real and exact experiments; but, the agreement is limited to capillary tubes, in which it must be supposed that the threads run in an almost parallel line to the guiding walls. For tubes of final transverse sections, and especially for canals and rivers NAVIER's formulae gives a considerably greater speed than has been in reality observed. This phenomenon is attributed to the deviation of the threads from their straight and mutually parallel direction, consequent on accidental irregularities, such as inequalities in the walls, modification of

pressure on the free surface etc. The new resistance resulting here from, which seems to be the result of accidental causes cannot be defined theoretically with desirable exactitude and it diminishes with the reduction of the dimensions of the transverse section of the bed. Nothing, however, proves that this vague resistance really arises from accidental causes, for it always exists, even when the walls are quite even and the current quite uniform. It should be observed that all physical phenomena, so long as their reciprocal relations have not been studied and determined, that is to say, so long as the laws which regulate them have not been discovered have always appear to be arbitrary. For this reason, the hydrodynamic problem in its present state must comprise observations of the deviations of water-threads from the parallel of the walls of the tubes on the bottom and the banks of the fluvil bed, with the view of discovering the laws which govern these deviations.

Based on the admission that the movement of the water takes place according to straight and parallel threads, there have been deduced from the formula of Navier other formulae on the established and uniform movement of the water of rivers. Modified and simplified by several specialists, these formulae give for the average speed of the current certain algebraical terms in which enter several fixed coefficients dependent on the resistance of the current. Such are the formulae of Prony, Dupuis, Girard, Hagen, Weissbach, Eillett, Chézy, Darcy, Saint-Venan, Hymphreiss and Abbot, Gaulkler etc. The inexactitude of formulae arising from irregular admissions in their foundation is rectified in their practical application by the value of the coefficients, which, therefore, must be determined with the greatest care. The inexactitude of the formulae is manifested by the difference in the coefficients in conditions, which, if not identical, are very similar. Thus, for example, the coefficient C for the formula of Chésy

$$V = C\sqrt{RI}$$

has been defined by several investigators, and by each one differently, and the diversity of this coefficient is above all strongly manifested in the calculation of the dimension of the bed. Consequently Ganguilé and Kutter considering this coefficient as a variable quantity, which is modified according to changes in the elements of the current which enter into the formula of Chézy have given for the coefficient C a term in which, besides the elements designated enters still a new coefficient expressing the result of the calculation of the degree of inequality of the bed. This coefficient must be obtained by means of repeated measurements of the speed of the current and of the slopes at different places. Such modification of the formula, although not adding to its exactitude allows of its more approximate adoptation, to practical objects, and it is for this reason that it is considered to be as the present day the best mode for the solution ot questions regarding works for the regulation of rivers.

Helmholtz working at the investigation of the science of the movements

of fluide, that is of the supposed movement independent of the force of gravity, of friction and other resistances, and considering the possible modification of the elements of fluid to be infinitely small has found that these modifications may result from a change of form in the elements, equally as from their relative rotation.

HELMHOLTZ has further stated the following conclusions:

The commonest and infinitely small motion of fluid particles consists in a continually advancing movement, rotation and extension.

The properties of the movement are as follows:

1°. A fluid particle that does not always rotate never rotates.

2°. If a line be drawn through a fluid particle every where parallel to its axis of rotation, this line remains always and in all places parallel to the axis of rotation. Every such line continually consists of the same particles. These lines are the lines of motion. The lines which pass through a surface element form a thread of motion.

3°. The product of the speed of motion and the section of a thread of motion is constant.

4°. Threads of motion can only return into themselves or end on the surface.

Since HELMHOLTZ, other mathematicians have studied these threads of motion, but no clear explanation of the motion of the water has yet been arrived at. The hypothesis of HELMHOLTZ has many partisans, but it is only the *possibility* of moving lines and threads in moving fluids which can be admitted, their real presence in flowing water is, however, not proved. The rotation of the unfinitely small elements of fluid cannot be observed, and observations by means of floats, of which we will speak later on do not manifest any rapid rotary motion. The rotation of the floats is very slow and is caused by the inequality of speed in the threads of water working on each side of the float. It is to be remarked that the line followed by a floating body never crosses itself, that is, it never takes the form of a knot, so that completely closed circular movements can only occur in places where the surface of the water is not under the influence of the current, as, for example in small bays, behind bridge piles or in what are called dead corners at junctions with confluent rivers etc. The rotary motion of the water in the vortex is not analogous to the supposed movement of the fluid in the lines and threads of HELMHOLTZ, for in the first case the axis of rotation is found outside the moving body (axis of cylinder) and in the second it coincides with the tangent of the line of direction, which, thus represents a curve enveloping the axes of rotation. The movement of the veins should rather be called spiral, for this last definition would admit of resemblance to the movement of aerial vortices, which in the same way as water-whirls move round a vertical axis.

BUSSINCSK recognising the existance of a rotary motion of the molecules in a current of water, considered their speed to be subjected to great irregularities;

for facility of calculation he introduces a new admission of the existence of average local speeds, nearly constant at all points of the mass of water, allowing at the same time that the water threads are almost parallel to each other. Like NAYIER, he introduces into the formula a coefficient of friction, which is not constant for the total mass of moving water, but changes with the alterations of the coordinates and is besides dependent on the size of the radius under water, of the form of the section, of the velocity of the current and of the value of the coefficient of interior friction. Thus BUSSINESK considers the actual movement to be unequal and gradually changing. Ad his admissions with regard to average velocities and, especiallly, as regards parallelism of threads are not in accordance with reality, and those referring to the variable value of the coefficient of friction are conjectural and arbitrary, we find that notwithstanding the importance of his works, which throw light on several phenomena concerning the longitudinal section of rivers, many things still remains unexplained and we have no exact formulae of the movement of water adopted to a practical and precise application in the same way as the formulae existing for the movement of solid bodies.

For researches concerning the displacement of fluvial alluvion it would be very useful to have exact mathematical terms for the pression of a moving liquid body on solid bodies; but unfortunately the empirical formulae in use are not only inexact, but their correctness even is very doubtful.

According to the general opinion of those who have studied the subject the question of the mutual pression of liquid and solid moving bodies is the part of hydrodynamics, whlch has received the least attention.

The cause of this is principally the admission of the parallelism of threads. The influence of this on the inexactitude of deductions is very strong, for not only is there no parallelism in threads of moving in quietly flowing currents, bnt shocks against solid bodies produce new movements of confusion,, accompanied by the formation of currents in all possible directions and which have not been explored.

Absolutely exact as are the formulae relative to the movement of solid bodies, little certain is up to the present known of the correctness of formulae relative to the shock of liquid bodies. Let us examine, for instance, the most brief deduction of the most exact formula, representing the shock of a single thread of water against a smooth surface which is perpendicular to it. Designating the acceleration of the moving point by p, the time by t, the space by s, the speed acquired during the time t by v the mass of the body by m, the density $\triangle$, the volume Q, the power of the shock P, the gravity of the weight of the body by G, the acceleration of the gravity by g and considering that $P = m \cdot p$, and $G = m \cdot g$, we shall have successively:

$$v = p \cdot t,$$

therefore: $t = \dfrac{v}{p}$.

$$s = \frac{v}{2} \times t = \frac{v^2}{2p}$$

$$\text{further } p \cdot s = \frac{v^2}{2},$$

$$p \cdot m \cdot s = m \cdot \frac{v^2}{2},$$

$$P \cdot s = m \cdot \frac{v^2}{2},$$

the second part of the equation we name conditionally active power which is equal to the force required to communicate to the mass m the speed v. If $t = 1$, we obtain

$$s = \frac{v}{2},$$

$$\text{therefore } P = m \cdot v = \frac{Gv}{g} = \triangle \cdot Q \cdot \frac{v}{g} \qquad (1)$$

In adapting these absolutely exact dynamic formulae to the power of the shock of a single thread of water, it must be calculated that the volume Q equals the efflux of which is expressed, as is known by the area of the transverse section of the thread of water multiplied by the average speed of water. That is to say $T \times v$; we obtain:

$$P = 2 \triangle T \frac{v^2}{2g} = 2 \triangle T \cdot h, \qquad (2)$$

in which h is the height of a colomn of water corresponding to the speed v. A similar application of the formula (1), which has reference to the shock of a solid body to a liquid mass is irregular, because the efflux of water can be equal to the average speed, multiplied by the area of the transverse section of the thread of water, only in cases where the threads are in the same line as the smooth surface; this is however not possible, as the water threads are not parallel to each other. However, experiments which have been made for the verification of the above named formula by M. Bidon have given results which approximate confirm its exactitude. This is to be attributed to the circumstance that the quantity of water directed in the tube can be immediately measured, instead of being calculated by the multiplication of the area of the active section by the speed of the water. (Plate I design I). Nevertheless, the quantity of the pression on the surface depends much on the dimensions of tha surface and above all on its distance from the orifice of escape of the water from the tube, so that Bidou when he placed the surface near the orifice of the tube obtained the result $P = 1{,}5 \triangle \cdot T \cdot h$, and according to Dubois and Langsdorff $P =$ only $\triangle \cdot T \cdot h$.

The force of the shock, in reality, is generally less than is calculated from the formula and this results from the fact that by the shock of the liquid mass a considerable part of the energy belonging to it is lost by the shock of the separate threads against one another. With the shock of a liquid mass against a solid the latter only receives directly the pression of the particles of liquid, infinitely thin, which come in immediate contact with it, while the entire

mass of the liquid particles transmits a shock from one to the other of the particles, in consequence of which the direction of their movement deviates strongly from the direct line of the solid surface and there can be no question of the parallelism of the threads. The greater the speed of the water, that is to say the greater its pression in the tube, the more must be, with exact experiments, the nearness of the coefficient in formula (2) to the given figure 2.

In the experiments of BIDON the speeds were very considerable, not less than 8 metres per second; with small speeds it must be supposed that the coefficient of the formula (2) may be considerably less than the unit, even as much as less than the half of the result of the calculation. So that the formula of the shock of a single thread of water, looked upon as the most exact of formulae concerning the shocks of liquid bodies really does not possess the desired exactitude; and the incompatability of the results of experiments with these calculations proves the inexactitude of the admissions made in the transformation of the formula (1). Also, it should be observed, that the pression on the surface at the time of the commencement of the efflux of the thread is more considerable than it is during the course of its flow. However for a mathematical expression of the shock of an unlimited mass of water we have no other means to apply than the formula (2) which is composed for the shock of a single tread of water. Therefore for this part of hydraulics we use the following phrase: *It is very probable* that we may admit that the laws governing, the shock of an unlimited mass of water are the same as those relating to that of a single thread of water. According to this supposition or admission the pression of a shock of water on a solid body on the side of its affluent equals

$$K_1 \cdot \triangle \cdot T \frac{v^2}{2g}$$

in which K_1 is the numerical coefficient defined by experiments and dependant only on the form of the body. Besides should be taken into consideration the relaxed pression or the want of pression (according to DUBOIS, non-pression). This can be expressed in the same way as the pression on the side of the affluent by the formula

$$K_2 \cdot \triangle \cdot T \frac{v^2}{2g}$$

The hydrostatic pression being equal on each side of the body in opposite directions may be left out of account.

Therefore, the result of the pression of moving water on a solid body may be expressed as follows:

$$K_1 \cdot \triangle \cdot T \frac{v^2}{2g} - K_2 \cdot \triangle \cdot T \frac{v^2}{2g} = K \cdot \triangle \cdot T \frac{v^2}{2g} \qquad (3)$$

All the coefficients K_1, K_2 and K are to be defined by means of experiments and will be certainly very different under various conditions and to

different observers. If for a single straight thread of water we may admit; with a certain degree of approximation, the efflux of water to be equal to the product of the area of section and the speed, such supposition can not be admitted for the movement of an unlimited mass of water, for it is impossible to suppose that the entire quantity produces a shock against a solid body through one cylinder which is separated from it and which has for basis the transverse section of the body attacked. Even with parallelism of threads the beds of moving water surrounding the cylinder participate in the shock in consequence of their connection and in consequence of the adhesion of the water to the eliminated cylinder. But as the threads of water have convergent and divergent directions, and as it is not possible to separate from the mass of water, the threads working at every moment on a solid body, the formule (3) may give results which may diverge as much from the real quantities as the volume of the cylinder may differ from the volumes of one or several truncated cones. The convergence of the threads of water does not conduce to condensation of the water, nor to the accleration of the speed of the current, which, on the contrary is lessened by the shock of the threads one against the other, and only causes an increase of pression on the solid bodies encountered on the way of the moving water. As proved by repeated observations the threads of water form curved lines which are still more curved when they turn around a solid body. When we say that a thread of water shocks against a solid body we do not mean that all the mass of the thread of water enters into contact with a solid body, but that on it is directed the action of the thread of water which is transmitted by the intermediary beds of water. An indefinite quantity of threads may work upon a body from different sides at any moment; they meet in their movement some resistance from the solid body; this resistance being communicated to them by these intermediate beds of water, they deviate from their direction and prolong this movement around the solid body with decreasing speed.

As the laws which govern the direction of particles of water are unknown to us, we cannot follow the threads which in the mass of water, press on the solid body in the bed of the river. But in order to throw some light on possibile cases of transmission of pression, let us suppose that their laws are known and we will represent them by lines as shown on Plate I fig. 2. Then, suppose a solid body of small dimensions, for example a stone in the bed of the river submitted to the hydraulic or, to the active pression of the body of water moving towards it. In order to determine the strength of this pression, we must seek out in the lines the points in which at a given moment are found the moving particles of water; and in these points draw tangents to the lines, which tangents show the direction of the pressure at the given moment. Looking at all these tangents, which cut the solid body we see a mass of straight lines convergent or divergent, which form one or several truncated cones, lying with their upper or lower end against the solid body. In the first case the body will be submitted to the hydraulic pression of the

convergent threads and of the greatest number of the particles of water, in the second to the pression of the divergent threads and of the smallest number of particles of water. Supposing these particles of water to be mutually equal in their mass, which we take as unit, if we define the average speed by v and the number of particles by m, we find for the active power or the mechanical work the mathematical term

$$m \frac{v^2}{2},$$

and for the force of the shock (P)

$$P = m\ v,$$

in which the quantity $m\ v$ represents what is called the quantity of movement. It is evident from what we have just said, that the figure m, or the moving mass of water on a solid body is a variable quantity and must not be eliminated from the formula by substituting for it the product of the density of the water with a determined volume. It is, also, evident that with the same speed at the bottom, but with alteration of the mass of water producing the pression. the alluvions may be submitted to a hydraulic pression different to the flowing water according to the disposition of the threads.

Observations on water-threads show that in deep waters, ordinarily disposed in the concave parts of the bed, all the water-threads move the floats towards the concave banks, from which it is evident that the hydraulic pression moving the floats is always directed towards these concave banks, while the particles of water follow lines which never have a point of intersection with the bank. So that the conception of the convergence and divergeuce of the threads of water and of hydraulic pressions must not be identified with the idea of the compression of the molecules of water, by the reunion of the threads of water.

Directing themselves by curved lines and moving between themselves the threads produce impulsions in two directions; firstly the tangent lines, which we have examined above and, secondly, in the normal lines, so that impulsions in the directions of the latter may induce rotary movements of molecules ot water contributing to the accumulation of alluvion. By the transformation of the active force $\left(\frac{v^2}{2}\right)$ in two directions its quantity must gradually be consumed and proportionately more as the angle of the convergence of the water-threads is larger. The reduction of the active force of each separate molecule of water in the mass admitted as unit must be expressed by the reduction of the speed of the current on all the bed.

In fact, as the curves of the bed are stronger the more remarkable is the depth produced by a great pression of water on the bottom, caused by the convergence of the water-threads towards the concave banks. The importance of the increase of the mass of the converging water-threads is seen iu the

following of the fluvial bottom along the concave banks, which occurs with the slackening of the current and causes the formation of a dead-water in the longitudinal section of the river.

The cause of the reduction of speed and the increase of dead-water, is, as has just been said, the consumption of a considerable part of the quantity of active power for the shocks of the threads one against the other in the normal directions of the molecules of water. On the contrary, in the deep parts where the water-threads have divergent directions, opposite phenomena are manifested and the displacement of alluvion in spite of the enormous speed of the current is effected slowly. If we were to imagine in the direction of the tangents, molecules of water as, for instance, thin threads of water moving against a solid body, all the quantity of the mechanical force would at a given moment be employed in the shock, of which the volume would perhaps be sufficient not only to move the solid body forward, but even to crush it; and the molecules or the mass of moving water towards upstream would be unlimited. But in reality the shock of the moving water is transmitted in a different way.

1° Each molecule approaching the solid body parts with, in the shock, only a part of its active power and diverging sideways keeps by far the greatest part of this power for its further flow.

2° Repeated observations have shown that the resistance of the solid body to the free movement of the water flowing towards it does not extend to all the mass of water flowing upstream, but that the deviations of the molecules commences at a certain dis ance from it, so tbat neither theoretical calculations, nor actual observations enable us to determine this distance.

It is probable that it depends on the velocity of the current, on the proportion of the area of the greatest transverse section of the solid body to the area of the transverse section of the bed, on the shape of the body and on the disposition of the water-threads.

Examination of the pression exerted by flowing water on a solid immovable body immerged in it has shown that there being no data by which the mass of water transmitting the shock to the solid body and submitting to deviation from the resistance offered to its free movement by the body could be determined, it has not yet been found possible to give to the expressions $m \frac{v^2}{2}$ and $w\ v$, a propre form for practical calculation. These formulae, however. are correct in their simple, form and very suitable for general decisions, relative to transport of alluvion by flowing water. As we have already said, the part of the flowing water working on a solid body, does not expend in the shock all the quantity of its active power, as for its complete use $m \frac{v^2}{2}$ would be equal to O, and this is only possible if $v = O$, that is to say when the mass of water is completely at rest. In reality it continues to flow with a some-

what relaxed speed v_1 preserving a working power of $m \frac{v_1^2}{2}$ so that the quantity of power expended in the shock is

$$m \frac{v^2}{2} - m \frac{v_1^2}{2} \left(v^2 - v_1^2\right). \quad . \quad . \quad (4)$$

and the power of the shock $= m\ (v - v_1)$.

The greater the power used the stronger is the shock and thus greater the possibility of removing the solid body from its place.

As the practical problem of the improvement of rivers consists above all in the deepening of the bed we must next examine by what means an increase in the value of the terms

$\frac{m}{2} (v^2 - v_1^2)$ and $m\ (v - v_1)$ may be obtained.

Examining these terms we see that the work of deepening and the force of the shock increase in proportion to the inerease m of the mass of molecules of water directing their pression on the projections in the bed, in proportion to the increase v of the speed of the flow of these molecules and in proportion to the decrease v_1 of the speed of these same molecules when they are sent back by the resistance of the projections in the bed.

For the increase m it is necessary to direct to the suitable depth the largest possible quantity of water-threads so as to concentrate their shock at this place. In practice this is obtained by shutting of the lateral arms, as well as the crossing threads which break themselves on the bottom, by means of regulation works which form a guide for the direction of the lines of water.

The value v is the average speed, not of all the transverse section, but only of that part of it, with which the hydraulic pression of the water extends to the river bed. If the quantity v increases and decreases with the average speed of all the section, it must be admitted that the decrease of the section must serve to augment the quantity v and consequently to augment the deepening power in the bed. With this object the narrowing of the bed is effected by works of regulation, it must however be remarked that the reduction of the width of the bed does not always give the desired reduction to the area of the section, for the latter is often found in a manner non-normal to its projected line but follows its curves in lines which are oblique, so that the water-threads take also a direction not only non-parallel to the projected banks, but sometimes are nearly straight; so that the width of the transverse section passing by the ridges of sandbanks may in these cases appear comparatively narrower than its primitive widths. Consequently projects of the configuration of a river compiled according to ordinary systems and the works of regulation executing according to these projects do not afford the desired depth of bed. For this reason it is necessary to take measures for the desired disposition of the water-threads and with this object to form regulation works to direct the water-threads so that they give the desired configuration. Besides, as is known, the

narrowing of the section has still the defect of causing with the deepening of the bed, the lowering of the level of the water and the displacement of considerable inclines of water towards neighbouring parts of the river, thus again causing new hindrances to navigation. It is true, that this could be remedied by submerged banks. which maintain the strong slopes in the regulated sections; such constructions are, however, very dear and they may become temporary hindrances to navigation if the amount of water diminishes or the draught of the vessels increases.

The quantity v_1 that is the average speed of the molecules of water which diverge in their movement under the influence of the resistance of the projections in the bed, against which they rush, enter in the mathematical expression for the power expended for the deepening of the bed with a negative sign and for this reason in increasing the depth attention should be paid to all possible reduction of the quantity v_1.

To examine this question let us suppose that a single thread of water is directed in a tube against a solid body firmly fixed at its end. If the solid body is not displaced by the force of the shock of the thread, the water in the tube will be brought to a stillstand, v_1 becomes $=$ o, and the entire quantity of the mechanical power $m \frac{v^2}{2}$ will be expended in the shock of which the force will be equal to $m\ v$. If the water-thread is not confined in a tube but flows freely, the water surrounding easily the sides and the upper part of the solid body, will keep after the shock a considerable part of its speed and the shock be incomparably weaker.

When the water-thread working on the solid body is surrounded by other threads nearly parallel among themselves or even divergent its action on the solid body will be greater than that of an isolated thread, for its flow around the solid body will be somewhat hindered by the resistance of the neighbouring threads. If the direction of the neighbouring threads, even when they do not direct their shock against a solid body, becomes convergent, it will be still more difficult for the attacking water-thread to turn at the side of the body and it will then flow over it. This way will be difficult when there are other water-lines in a position above the attacking line, for the latter will have to lift them up. In the same degree as the difficulties in encircling the solid body increase the speed of the water-thread v_1 diminishes and the shock increases. The more water-lines there are above the solid body, or with other words the greater the depth of water, the more difficult it becomes for the attacking line to lift up this mass of water, until at last at a certain depth it is no longer capable of this action, in which case v_1 reaches its minimum and the force of the shock its maximum.

It should be remarked that v_1 in the river bed never equals o, for the attacking water-thread may flow around the body increasing the speed of the current of the neighbouring threads without lifting them up to any extent. It is evident from what has been said above that the increase of depth and

the convergence of water-threads contribute to the increase of the action of the water in the river bed, but it must not be concluded that an artificially created channel in the river bed could be preserved and increased by the action of the current; as for this to be effected would be required, not only the depth of water but, also, the disposition of the convergent threads of water directed on the projections in the bed. And without this last condition there would be scarcely any current in the channel, which would be obstructed by particles of solid matter moving above and plunging into it on account of their weight.

The considerable influence of the depth on the formation of the river bed is confirmed by observations on cuttings. When a cutting is formed at a small depth, for instance, 0.4 to 0.6 meters below the level of the water, the deepening of the bottom takes place very slowly and this in spite of the enormous incline existing at times of low-water and in spite of the considerable speed of the current; but at high water when the fall is less the operation of deepening becomes so strong that, as I have repeatedly had occassion to observe on the Dnieper and on the Pripet, the section of the cutting becomes in a very short time sufficiently large for navigation.

These results will show that the deepening power increases, not with the speed of the current, but in accordance with the augmentation of the mass of water working on the deepening, and especially at an increased depth, the water by its gravity does not allow its lower beds to pass over the inequalities in the bottom, but carries them away in descending the stream.

Generally, the more that the circuit of water around a solid body is hindered, v_1 is less and the force of the shock and the power expended by the water for the shock is greater. We know, for example, that small streams flowing in narrow beds with banks but little excavated often carry away enormous stones. In the same way rainwater in the gutters of the streets carries with it bricks and stones with a speed not much less than that of a river current; but in wide river beds even small grains of sand remain. The difference of the quantity of the power expended in the displacement of the solid bodies in these two cases, does not depend so much on the speeds of the current v, as on the quantity of the lost speed $v - v_1$, that is to say on the quantity v_1, and the latter again depends upon the great difference in the proportions of the transverse sections of the objects carried to the sections of the beds, or to the quantity of the narrowing of the section of the current by the transverse section of the body moved. If the bed be large and the size of the solid body small, then v_1 differs very littie from v and the quantity

$$\frac{m}{2}\left(v^2 - v_1^2\right)$$

is nearly $= 0$. If the current be narrow and the transverse section of the object which obstructs the free movement of the water, larger, a considerable delay in the movement will be caused, that is, v_1 may become much less than v, and a part of the mechanical power of the water which is expended

on the shock may attain a quantity sufficient to displace even heavy obstacles. With regard to a closer examination of means for the diminution of the quantity v_1 let us suppose a flowing water in a gutter barred at its end by a solid screen. After the shock of the water against the screen ,v_1 will be $= 0$ and the shock complete, that all the active power of the water will be expended. If, however, at the side of the screen a lateral piece of the gutter be removed the power of the shock against the screen will not be complete and will be in proportion as much less as the lateral opening is large. See plate I fig. 3.

If the screen be removed the water flowing direct exercises the least possible hydraulic pression on the walls of the tube. Exactly similar observations have been made in fluvial beds. Lines of water flowing against the concave bank and the part of the fluvial bed, which is contiguous to it being turned back lose a great part of the speed employed for the shock, and for the deepening of the bed at the side of the banks. On the contrary, in a straight bed the loss of speed in the stream is comparatively insignificant; v_1 is almost $= v$, and the power of excavation consequently very small.

Therefore to obtain the quantity of the $\frac{m}{2}(v^2 - v_1^2)$ by the diminution v_1 the straight parts of the projected configuration must be avoided and the windings of the curves enlarged as much as possible, that is their radius diminished. However this last measure has up to the present time not been practically applied, for the object of the regulation of rivers does not consist in the general deepening of the bed but, only the excavation of the bottom at places where the depth of water is insufficient, which places are generally found not in the concave elbows but at the points of inflexion of the bed. In any case the application of such a measure should be restricted within certain limits, depending; 1) on the disadvantage of sharp curves for navigation especially for steam tug navigation; 2) the underwashing of the banks; 3) the washing away of the submerged banks by the water at high tides which seek to follow a more direct line.

Thus in projecting the trace of the banks we must principally follow the configuration of natural concave banks, except in cases where their windings are feeble and irregularly developed.

At the points of inflexion of the bed great divergency is generally found in the directions of the water threads; and this affords them comparative facility in passing round obstacles.

The loss of speed is, therefore not great, v_1 differs very little from v and the transport of alluvion is weak,

To augment the value of v, we must unite the separate threads and give them a convergent direction towards the projected line of the channel, so that for the deepening of extensive beds the narrowing of the bed is not sufficient, but it is necessary to give the bed a configuration, which will cause the water threads to take always a convergent direction.

Consequently we find it possible to increase the excavating power of the

river bed, not only by increasing v, that is the average speed of the current, but also, by increasing the value of m and diminishing that of v_1.

To increase v is not sufficient to narrow the section; it is necessary that the water-threads have corresponding directions, and this is required, also for the production of the desired influence on the quantities m and v_1.

It is likewise acknowledged that the regulation of the bed may be effected, not by narrowing it, but chiefly by guiding the water-threads in a suitable direction, by which it is evident that a narrowing of the section will occur.

In examining the question of the action of the force of the current on the deepening of the bed, we have considered the inert power of the water as an independant cause, while the active power is supplied by the force of gravity of the water in its movement. We have, therefore, now to consider to what extent we are able to dispose usefally of this force of gravity.

If Q be the efflux of water, $\triangle$ the density and H the slope, we obtain as term for the force of gravitation the product of $\triangle \cdot Q \cdot H$.

The yearly efflux of water cannot be regulated, for this depends on meteorological and climatic conditions; it is, however, known, that the cultivation of forests conduces to the increase of moisture falling in the atmosphere.

But, for the maintainance of a navigation depth, it is not the general quantity of moisture falling into the basin of the river which is of importance, but much rather a suitable and regular supply of water. This is attained by forest cultivation near to the basin of the river and by construction of reservoirs. The general slope of a river or of a more or less great part of it cannot be altered; still, care should be taken that it be divided on the length of the river as far as possible in such a way as to obtain uniformity of the longitudinal section.

Formulae concerning the uniform movement of water teach us the necessity of regulating the slopes so as to obtain uniformity of longitudinal section of the bed of the river. But in the solution of practical questions of regulation of rivers a complete levelling of the bed is not necessary; the possibility of such levelling as well as of uniformity of the current is very doubt full, as the condition of the stream in the curves is very different to that in the inflexions. This disparaty is especially shown in the disposition of the water-threads, and if we could succeed in obtaining in the inflexions a convergence of threads such as are shown in the windings of the bed the question of levelling would be considerably nearer to an ideal solution.

The above examination of the application of dynamic forms to river currents shows the anomaly of the admission of parallelism of threads of water.

The very great difference of movement and of shock of solid, elastic and liquid bodies arrises from the fact that in the first the mutual position of the molecules and of the distances between them does not vary either during the movement or during the shock.

The direction of all the molecules is parallel or concentric, while in the

movement of liquid bodies, in consequence of the resistance of the surface, on which they move and the surroundings in which the movement is effected, there is in the interior of the liquid body a continual translation of molecules, giving rise to interior independent currents, and this consumes a considerable quantity of the stock of mechanical power acquired by the working of the force of gravity. This loss of active force is especially great in the shock of liquid bodies against solid bodies, since it consumes itself in the distribution and the shock of the threads. In order to place hydrodynamics in the rank of the exact sciences, abstract mathematical operations, such as those made by NAVIER, HELMHOLTZ and their disciples, BUSSINECK and many others are not sufficient.

It must be acknowledged that hydrodynamics is, just as physics, an experimental science and the bases of its conclusions must not be arbitrary admissions, but data acquired by generalisation and direct experiments. As the movement of liquid bodies in the midst of resistance are the result of laws, which govern the movements of solid bodies, we consider it a principal duty of those who make a study of the practical application of hydrodynamics, to examine the combinations of the movement of water, resulting from the configuration of the river bed and influencing its reformation, and especially to pay attention to the particularities of the movements of the water, by which liquids differ from solid bodies, that is, the interior translation of molecules in bodies during their displacement. The researches made under our direction on the Dnieper near Kief have shown the possibility of examining the direction of water threads relative to the surface of the water the particularities then discovered concerning the direction of water-threads connected wirh observations on the configuration of the relief of the river bed have contributed to the explanation of the established law of the disposition of isolated and independant currents appearing in every watercourse.

In order to solve the question as to the possibility of closing the lateral bridge openings in the dike of the Dnieper on the causeway between Kief and Tchernigoff and for the security of concentration of all the waters of high tides in one principal bed at the right side of the town, so as to conduct them into the opening of the suspension bridge, we have made, in addition to repeated measurements of the quantities of water, by means of floats, definitions of the dispositions and the measurements of the speeds of the water-threads on the surface of the water.

The floats are made round, of dry pine boards 0,06 m. in thickness, 0,25 in diameter (see fig. 1, Plate II). They are painted all round in a white oil-colour, the upper disk is divided in 4 sectors, varnished in different colours, so that the direction of its rotation may be observed from a boat at a certain distance and the number of revolutions counted.

An iron rod is passed through the float, having at its lower end an iron screw on which is fixed es many iron plates as are sufficient to siuk the float nearly entirely in the water. At its upper end is placed a glass ball of bright colour.

Before commencing the compilation of a plan of the disposition of the threads of water on the section under examination, transverse sections are drawn up at a distance of 50 to 44 meters from each other according to the importance of the section for the projected works, and according to the variability of the character of the bed. These profiles are indicated on the banks at each side of the bed by double stakes, as are shown on the plate. Then a plan of the sheet of water is made on a scale of 25 or 50 m. to 0,01 m. The entire section is divided into several parts, in such way that one plan does not show more than 600 to 700 m. on each side, that is to say, upstream and downstream, since at a greater distance with a KIPREGEL glass, the glass balls of the floats cannot be distinctly seen.

In accordance with rough notes on the duration, of the courses of the floats on the sections, plans have been made in two forms.

On the plans *a* are shown the directions of movements of floats and the profiles of their speeds; on the plans *b* are shown, also, the directions of the floats and their position at a certain lapse of time, after their passing the first profile simultaneously, theie were fixed on their lines of route, according to their speed, the points at which they were at a lapse of 2, 4 or 5 minutes after passing the first profiles; uniting these points we have the profiles of the position of the floats at the end of these given intervals. From these points in the direction of movement of the floats, the distances were traced which they had travelled in the same interval according to the time. The union of the points found, defined the second profile and so on.

In examining the positions of the lines of direction of the floats, it is impossible to overlook one particular characteristic, at the first view appearing a strange one; namely, that all the floats move from the convex banks to the channel and to the concave banks, and then their lines of direction cross.

And, as the points of these crossings have a certain fixedness, the fact cannot be attributed to accidental causes, such as currents of wind, movement caused by passing steamers, etc.; the more so, as these observations were made in calm weather, and passing steamers were warned by means of a speaking-trumpet to keep at a certain distance from the floats.

If the course of the float be considered as a water-thread, that is, as the route followed by a certain mass of water, the intersection of these masses, while they maintain each their own direction is evently impossible. For this reason it is necessary to examine in how far the course of a float coincides with that of the direction of a water-thread. Let us suppose a volume of water in a spherical form or in the form of a rotating body with a vertical axis placed on a quite smooth horizontal surface.

A fload placed horizontally above this rotating body will, after the water has flown off descend vertically. According to its movement as seen on the plan, we can only judge, that the water was quite motionless. If, however, the surface on which the water rests be not quite horizontal, or that there be hollows or projections in the surface and inequalities in different directions,

by the increase of speed and of active force, the float will be drawn in the direction of the greatest speed; from this, however, it does not follow that the water does not move also in other directions.

Likewise, because the floats move towards the channel and towards the concave banks, it does not follow that all the water moves in the same direction; it shows, however, that near the surface of the water the greatest speeds of the current are not directed parallel to the banks, but obliquely to the channel.

This deviation ot the water-threads towards the channel is the reason that the efflux of water, measured by us in different rivers gives sometimes results very different from their true value. The difference in this respect is much too great to be ascribed to want of precision in the instruments of measurement, for these may be brought to a great degree of perfection if the turning wings are carefully attended to and the coefficient of friction correctly defined. With the confluence of two waterthreads their masses unite and the further movement follows in the direction of the result of both their speeds.

The complete union of the two masses of water can be judged by the colour of the water, which is different on each river. Marshy rivers have a dark brown colour, mountainous rivers are transparant, others yellow, of a greenish shade and so on. This difference in colour at the confluence of two rivers is only observable at a certain short distance from the place of union, and gradually disappears as one thread of water connects itself with the other.

The float at the junction of two water-threads moves in the direction of the result of its own speed and that of the two threads. Thus, we find that at the confluence of two water-threads the floats carried by these threads will not unite and will not float together, but their lines of direction will cross and that if the place of union of the threads remains unchanged in a certain part of the bed, the points of intersection of the lines of direction are not altered. If a ship navigates a part of a river where another river or branch flows into it at a sharp angle and where the concave banks form a point, it usually passes into the thread issuing from the other arm.

The float receives at every instant a shock from the water which carries it but it always tends to follow a straight line at a tangent to the curve of the line of the thread. The mass of the water-threads oppose this movement of the float and tend to draw it in the direction of their route. This opposition is partly overcome by the active force of the float, so that the direction of its movement does not entirely agree with the line of the water-thread and the float deviates towards the concave bank and reaches it sooner than the thread on which it had been launched.

Up to the present it has not been found possible to define to what extent the float deviates from the direction of the thread which carries it, since the direction of the current is only to be observed by the movement of the floats. We will later on describe an apparatus which we have invented namely

a submarine vane, by means of which the direction of the current at any point of the transverse section of the bed may be determined.

If the density of the float were very nearly the same as that of the water and its dimensions infinitely small, its direction would coincide exactly with that of the water-thread.

It the float were of final and very small dimensions its direction would deviate very little from the movement of the mass of water surrounding it; and we may, therefore, admit that the deviation of a solid floating body from the direction of the mass of water which carries it, is to a certain extent proportionate to the dimensions of the body. The deviation of the float results from the power of inertia which is proportionate to the mass of the body, that is to say to the quantity of three dimensions, and the resistance of the water transmitted to the float by the shocks against its surface is proportionate to the dimensions of the surface, that is, to the quantity, of the two measurements; so that the power resulting from inertia and resistance is proportionate to a linear quantity, for example for floats, of equal height it is in proportion to their diameter. From the deviations in direction of two floats of different dimensions some idea may be formed of the extent of the error admitted, when it is supposed that the direction of the float coincides with the position of the water thread.

With the object of throwing light on this point we had a float made with a diameter of one meter, that is tho say four times as large as the usual size. Its organisation is shown on fig. 2, Plate II.

Observations on the progress of this large float showed that in weak curves it moved almost identically in the same way as floats of smaller dimensions. When the configuration of the water-threads is more curved the larger floats deviate more strongly than dö the small ones towards the concavities of the water lines. (See Plate IV thread N°. 5).

Generally the progress of a large float is less subject to deviation by the shock of lateral threads of water, than is a small float, therefore, it may be accepted that the floats follow lines which differ but very slightly from the directions of the water-threads.

We consider it here the appropriate place to give an explanation of the expression *water-threads*, an expression which we shall frequently use in the following pages.

By water-threads we understand a mass of water of indefinite amount, but, with a determined direction. This direction usually agrees nearly with that of the float. Its dimensions being undetermined, the water-thread is not a physical body, but a representation made ta explain the movement of the water.

In a river there are no separate water-threads of defined limits and extremities. The movement of the water is the movement, not of a thread, but of a mass, the same as the movement of a solid body, with this difference that all the molecules of a solid body describe parallel and concentric directions, while all the molecules of a liquid body, having different speeds describe curved lines, not parallel and not concentric.

On further examination of the plans attached to this work, it is impossible to overlook the characteristic particularity of the position of the water-threads near the hanging bridge. In the neighbhourhood of this bridge the threads gradually move away from the banks.

Thus, also, on the projection IX, Plates IV and V, all the floats are directed towards the right bank and against the concave part of it; the one exception being float N°. I on thə left side, which only travelled a distance of sixty meters from the concave part of the bed. The floats reaching the banks were obstructed by the fascines, only floats IV and VI glided on to a smooth surface of the bank, floated off it and descended farther with the stream. The inclination of all the surface of the water in the entire bed towards the channel, and towards the concave banks, therefore, from the shallow water towards the deep parts, is a great security to navigation.

Without this disposition of the character of upper currents, ships and floats would ground on sandbanks, where as under the present circumstances a ship has only to follow the stream and to take care that it does not strike against the banks. The current itself does not allow the vessel to flow against the sandbanks on the convex side, Floats navigate on the Dnieper and its branches in calm weather without being steered. It is only on account of this inclination of the water to stream towards the channel, that vessels find their way between the shallows. We have often heard navigators say that the best indication of the deepest waterway was shown by floating barrels filled with tar and joined together. As soon as such a reft is launched on the surface of the water it follows the deepest parts, except at curves where by the force of converging water-threads it is moved towards the concave bank.

The French engineer FARGUE, proceeding from the idea that the convex banks drive the water towards the channel, based on this his principal of the curved configuration of the banks on the inflexions of the bed.

But, if the channel attracts to itself the threads of water and if the convex banks reject them, we must ask from where comes the water on the convex banks and where does it flow to from the channel and the concave banks? We all know that the water on the convex bank is not staguant but has sometimes considerable speed of current; thus, for example, in the stream where a part of the hanging bridge on the Dnieper was temporarily removed, the current wăs so strong, that two tugs were required to drăw a vessel through it.

The answer to the question is very simple. The water flowing towards the channel and to the concave banks having no other possible issue, rises slightly and forms a transversal declivity in the channel from the concave towards the convex side and by its pressure on the under currents causes them to flow in the inverse direction and obliquely to the banks.

The existence of such an under-current from the channel towards the banks has not up to the present time been exactly determined, as correct instruments for the purpose of measurement do not exist, but it is confirmed by

many observations. Thus, for example, the excavations in sandy concave beds, by which large pieces of sandy, marshy soil are frequently carried away do not cause sanding of the neighbouring parts, and the water flowing along such banks apparently quite pure and transparent, while in the shallows it is cloudy and lifts a quantity of alluvion from the bed. This is because the earth loosened from the bank is carried away by the under-current, which distributes it not only over the lowest tongue on the same bank, but also in the direction of the opposite convex bank. In this way is explained the increase in the number of the tongues of land under wateı on the convex bank and the corresponding hollows in the concave banks in higher parts. The best proof of the presence of the existence of an under-current is, however, obtained by examination of the bottom of the bed.

If, in the bed there is a sandy elevation in the direction of the current, the grains of sand of the ridge of this elevation are thrown on to the lower slope down stream to be replaced by others brought from the upper parts of the stream. The upper slope is levelled, takes a slight incline, coinciding with the power of the water-flowing above it; and the lower slope, protected from the shock, becomes of a less incline. By the levelling of the upper ridge to a slıght slope and by the increase of the lower slope, the sandy ridge gradually descends with the course of the current. As the displacement of the particles of soil is effected on the side of the water-curent, the top of the sandy ridge is directed along the line of the water-threads, that is to say on the bottom-current.

These well-known appearances afford us a certain means of fuiding the direction of the stream frŏm the configuration of the bottom of the bed.

The soft banks which are visible at low water present a row of sandy projections which against the stream have a very slight slope ănd are rather steep on the side of the bank. This form of tongues of land on sandy banks which is everywhere observable, shows that there is in every river with an alluvial bed, a bottom current directed obliquely ăgainst the slighter sloped banks.

By examination, by means of a water-scale the direction of the sub marine ridge can be defined and its limits determined. It is sometimes found that these sandy deposits occupy the largest part of the width of the bed, reaching even to the channel; sometimes even they cross in the bed, so that at such places no channel really exists, at least, no channel caused by converging currents. In this case, the upper water-streads have a divergent direction, that is to say, that the upper convergent uniform current is replaced in these parts by an under-current, fan-formed, extending over all the bed.

The cuniform current converging towards the concave banks engenders by its shocks an under current in a direction lateral to the surface so that the current of the bed appears to be a consequence of the current of the channel. A more exact examination shows however that the working of both of the currents is dependant on different causes.

If we represent the transverse section of the bed with the speeds given on

design 4, Plate I, we see that these lines divide the section in different beds of water which move away gradually from the bottom and the banks towards the channel; the bed of water nearest to the channel is generally the one with the greatest speed.

The various speeds arise as is known from the exterior resistances to the current of water represented principally by the friction against the bed and partly against the air. If we leave the upper part of the bed out of notice and consider only the bed of water which has the greatest speed relative to the others we observe that flowing away over the others, it withdraws from the smooth surface of the section. Then, to fill the place, of these removed particles of water, all the molecules of the upper bed are thrown from upstream into it. Thus, the current of the comparatively rapid channel absorbing the water of all the bed is the cause of the deviation of the superficial current towards the channel or towards the concave bank near to which it flows.

In this way the water-threads arrive at the concave bank by the force of inertia and partly also by the result of centrifugal. Every bed and each thread of water which moves more rapidly attracts a neighbouring bed or water-thread; herefrom arises a deviation of the particles of water moving at a comparatively slow rate along the bank towards those moving more freely and more quickly in the channel.

To find the cause of the deviation of the stream of the bed towards the banks which have a slight slope we must consider the position of the water-threads in a vertical smooth surface. As is known, the direction of the wind blowing over the earth's surface does not follow a line parallel to it but at an angle to the horizon which is sometimes as much as 15°.

This arises from the friction of the air on the earth's surface and on its inequalities and projections. A similar phenomenon occurs with the movement of the water. The lower beds of water are arrested by the roughness and unequality of the bed; the upper beds pass in advance of the lower ones and descend before them to the bottom; there they are again arrested by the shock and the friction against the latter and overtaken by still higher beds of water. Thus the position of a water-thread in a vertical plan should be inclined towards the depth, so that the angle of deviation from the horizon gradually increases towards the bottom. There is to be observed in the upper-water beds a certain deviation in the water-threads from the horizon to the surface of the water, which deviation arises from its friction against the air. Such deviation of water threads from the horizontal direction is related to the shocks of surface in friction with the bottom and with the air and, with the consequent loss of mechanical power or of active force in the water-threads. This loss is accompanied by a lessening of speed in the current.

The upper current descending from the banks to the bed of the channel has a direction almost parallel to the bottom and levels the bottom while forming in it extensive longitudinal ridges; there are thus no isolated shocks against the projections in the bed, and the speed of the bottom beds of water

differs but little from that of the upper beds. On the contrary when the movement of the water is from a deep part to a shallow part, the lower water-threads strike much more strongly, against the bottom and the loss of speed be therefore more considerable. In fact the graphical representations of speeds measured in a vertical plan, present convex lines very nearly approaching the direction in the channel and have a considerable inclination towards the banks which are slightly sloped and towards extensive shallows. The inclination of the water-threads to the horizon increases the error in our calculations of the efflux of water. We can only obtain a correct calculation by multiplication of the speeds on a smooth surface with the normal sections, therefore the speeds on smooth surfaces must be determined for curved sections as well as for horizontal and vertical directions. As however it is very difficult to find in nature the position of these to be determined points, it is necessary when a section has been chosen to measure the direction of the threads at the same time as the speed of the current and to multiply the section not with the speeds, but with their projections on the perpendiculars on the plans of the sections. As the rectangular projections of lines are always less than the lines themselves, it follows that the actual efflux of water is really less than shown by our measurements.

The water-threads directed towards the bottom are the cause of shocks against it, they move grains of sand forward and rushing again upwards with them carry them down the stream.

A particularity of this kind of movement of alluvion is the great speed remarkable where there are extensive shallows. The power of the shock ot the water against the bottom is modified by the inequalities in the river-bed and accordingly each mass of sand as it is carried forward cannot directly cross the bed but forms single stripes of different forms which are in the middle at their highest and lower towards the extremities. The slope which is directed towards the upper stream is slight and the one towards the lower stream is sharp. As by the increase of the lower slope the upper gradually disappears, the masses of sand are thus continually moved down-stream; and their height, their length and their position with regard to the profile of the subject to continual change. These changes are caused by the fact that the water which rushes against the sandbanks does not flow over them but flows of at both sides where the height is less.

The water thrown of the sandbank forms a new stream which is directed against the top and the two sides of the ridge and observations show that the alluvion moves more in the directions of the two sides than over the top. The smaller grains of sand are carried by the water from the top and deposited on the bed at some distance down stream where they form the beginning of a new ridge. The movement of alluvion is thus caused more around the ridges than over their summits.

The ridges formed lower down are opposite the upper ones. Generally the ridges are not found on the horizontal part of the bed but on the slopes of

the banks. The water-threads flowing round the ridges have a greater speed in the direction where the resistance is less; as the principal resistances of the movement of the water-threads from above consists in the weight above them, the water rather flows round the ridges sideways where the depth is less, that is towards the bank.

By each shock of the bottom current the greater part of the water deviates towards the bank; thus the union of the mass of these continually moving impulsions causes a deviation of the stream towards the bank and a flow of water in a fan-like form towards the shallows.

With regard to the causes of these bottom and upper-currents, we acknow ledge that they depend upon the form of the profile of the transverse section of the bed, which is deep in the channel and has a soft incline on one or both of the banks. We must, however, not conclude that these currents are due to the existence of such a profile, on the contrary, the formation of the profile of the bed arises exclusively under the influence of these currents, without which that is to say, with a parallel waving movement of the water, the transverse profile would be nearly a trapeze.

In consequence of the current of the cuneiform channel descending towards the bottom, the smooth bed of the river within the limits of the stream must have a triangular form of transverse section; the point of this triangle is only observable in rivers with a more or less even efflux of water. Generally the position of the axis of the stream of the channel varies in every river according to the alteration in the height of the horizon and the efflux of water. This is the cause of the triangular profile becoming obtuse at the rounded points, and at the lower sides, rather concave, so that the profile of its form approaches a parabola.

The upper part of the slightly sloping banks form convex curves in the transverse section, so that the active force carrying away the alluvion of the channel towards the bank, gradually diminishes; therefrom the slope of the bank on which the particles of sand are moved, becomes less sharp. By this we are able to approximately determine, by means of the shape of the transvers section; the limits between the converging and diverging currents, which limits must be near the point of inflexion at which the concave part of the profile becomes convex (Plate I design 5). With the translation of the channel at the inflexions of the bed from one bank to the other, its transverse profile may take all imaginable irregular curves.

We are able to observe on a small scale the way in which flowing water works on the profile of the bed, according to its movement in two streams, the one in the channel and the one on the bank. For this purpose we have only to follow the course of a mass of rainwater flowing in ground which is easily hollowed out.

Even on the smooth places of the surface of the ground there are always some parts which are lower, towards which the water firstly in a wide stream directs its course.

Where the thickness of the stream is the greatest, is seen the greatest speed in the upper water, because the resistance caused by friction and adhesion to the surface of the ground upon it, has then its least influence.

In any case an accelerated movement of the water arises; this attracts the threads ot the neighbouring parts on the bed, hollows out the ground and causes a deepening in the bed, in the parts, lying under the converging currents. At the same time, appears a current on the bottom which, arises in consequence of the shock of the water in the direction of its quickest threads.

The converging current causes longitudinal cavities, which are especially deep in their curves, and the bottom current rejects the soil on the slightly sloped banks and on the widenings of the bed, and that in a wavelike form. In a very short time the bed has depth and sandbanks of great extent which are distinctly visible when the bed is dry.

According to the laws of its current the water does not only follow its bed in porous and dry grounds. but, also in those which are hard and rocky. Of this proofs are found on the Dnieper. The old way, called the cossack-way used by floats in the spring, flows in the deepest part of the rocky bed.

According to the explanations of persons well-acquainted with the cataract district of the Dnieper these channels owe their origin to accidental fissures in the rocks, these having suffered, in their less solid parts, destruction by the rushing out of the water. If however, we examine carefully the conditon and the direction of the old channel, it will be seen that this explanation of accidental origin is unfounded.

The ancient waterway is situated near to the right bank and is the natural channel of the Dnieper in the cataract district. The new channel at low water, affords an excellent course for entering and leaving the canals. They are constructed near the left bank in parts which are less deep and less dangerous.

The natural deviation of the channel is in our opinion due to the action of the northeast wind extending over centuries.

We have proved in a previous report that the steepness of the right banks of rivers flowing southwards is not caused by the earth, rotation, but by the influence of the wind at the time of the passing of the ice in autumn. The greatest degrees of cold in our climate, which cause the ice on the rivers, occur only with north and east winds. The culting power of the ice in autumn is so great that it is sufficient after a few hours to divide a beam of 0,25 m. in diameter. The current of the water itself has scarcely any effect of friction on wood.

The steepness of the right bank in the cataract district and the approach of the old channel to this bank are therefore not due accidental causes but almost entirely to the effect of the northeast wind.

The rocky bed of the cataracts has a depth for floats nearly sufficient for their passage even at low tides. The obstacles are the summits of rocks, which cross the bed in a straight line and aie called *laves*. Throug these laves the old channel takes its course towards deepcr parts where there are no rocks rising out of the bed.

If these deep parts were of an accidental origin, the old channels in the cataracts would be curved, and have a winding direction when passing from one lave to the other; in reality however the channel runs in a straight line through the mutually parallel rows of laves. It is impossible to suppose an accidental piercing of the laves at all the cataracts in the same perpendicular line; we must therefore be convinced that the deepening and the natural washing away of the laves is caused by the water in the direction of the channel.

The absorbing power of the converging stream is so great, notwithstanding the small width of the channel (at most 40 to 100 m. with a river-width of 700 m. that a vessel launched at some distance from a cataract, in calm weather finds, itsself, its way into the old channel; and is then carried by the converging current over all the laves. To guide the vessel well, it is only necessary to take care that it be not caught by any lateral current; for this purpose a rudder is used which is formed of several planks.

If the converging currents were not as we have just described, the passage of floats in the cataract districts could not be effected.

There exist, therefore, in the bed two currents; the upper one, convergent and cuneiform, which, descending to the bottom of the channel causes there longitudinal excavations, and might be compared to a plough throwing the earth up on each side of it; and another at the bottom, divergent and fan-shaped which gradually deviates from the convergent direction along the channel to a direction nearly normal to the banks.

The soil washed ont by this second current and thrown on to the concave banks forms slopes with slight declines and drives in zig-zag lines slantingly over the ridges of sand.

If we could examine the direction of a single particle of water it would at first sight appear to us to be very irregular especially on account of its different and apparently accidental deviations from its normal direction, which are caused by the projections in the bed and on the banks produced by the continual variation in the flowing quantity of water.

A particle of water in the outer layer a short distance from the banks takes a slanting direction towards the channel and when it has reached it, falls slowly down, and then travels quickly over the bottom, in a line almost parallel to it. It then turns on one side and joins the bottom current, rushes against the foot of the slightly sloped banks, thereby losing the active power acquired in its movement along the channel. Now it springs sometimes upwards, sometimes downwards and so continues on its way, until it joins again the upper water bed, with which it again descends in the direction towards the channél.

The sharper the curve of the concave bank, the more rapid is the descent of the particle from the upper beds towards the bottom, the greater is the active power acquired by the movement and the greater the excavation of the bottom. For this reason the depth at the hollowed parts agrees in inverse

ratio to the radius of the curve; still, the parts of greatest depth are not found exactly opposite the largest curves of the concave bank, but slightly lower down stream where the water particles which have the most active power reach the bottom.

In this way arises the constant mixture of particles of water, without which, that is, with a direction parallel to the threads, the rapid mixture of the coloured or troubled water of the affluents with that of the river, would not be explicable.

The upper converging current arising from the bottom current, after depositing the alluvion, directs itself towards the channel; therefore this upper current is of clear water, which causes no deposits in the channel.

If the power of the converging current is strong enough to hollow out the concave bank, this power is also sufficient to carry away the loosened earth of the channel and without obstructing it, deposits this soil ou the slight slopes of the banks. Freed from this alluvion, the bottom current arises at the surface of the water and is transformed into the upper current of a pure form and flows again to the channel. In this direction of currents the channel with the exception of accidental causes can never suffer from deposits of sand. The sand can only descend in a tongue form upon them from up-stream. Only at low-water and when the transverse section becomes exceedingly large in proportion to the reduced quantity of water, the bottom may receive a slight deposit of mud.

The depth and constancy of the navigable bottom are thus the effect of the converging current, therefore, in regnlation of rivers in the interests of navigation care should be taken to grand to this stream the fullest possible extent. It must, however, not be forgotten that to have a convergence of waters, it is necessary to admit a free divergence by a bottom current on the tongues and the slight slopes on the banks, considering that it is only by its equal divergence that the bottom current can be translated into the upper current, and proportionately supply the channel with the water threads of the converging current.

The converging currents are directed against the concave banks not in consequence of centrifugal force; as is often seen and still more frequently in regulated parts of rivers, there often exists a beautiful channel commencing on the concave bank, and continuing along a great length of the convex bank, which serves as a prolongation of the concave bank. The converging current towards the concave banks results exclusively from the concave situation turning progressively to the side of the bed; it constantly reencounters the current of the channel which deviates from it, divides again the water threads flowing towards the concave bank and in consequence of the hydraulic pressure hereby caused is directed towards the bottom which it excavates.

At the same time the bottom current following the convex bank, being transformed into an upper current supplies new water threads to the bed which flows towards the channel. For the maintainance of the converging

current, all that is necessary is to give a sufficient curve to the convex bank, for a constant intersection with a direction of the returning water threads of the converging upper current. Not only the concave bank may be treated in this way. but on a proportionately short extent, also the convex; therefore the convexity of the bank should project considerably in the bed and be turned against the current with the object of meeting again the water-threads flowing towards it. Therefore, the more the convexities forming the extremities of the concave banks are developed, the more they retain near them the convergence of the water.

We have verified this principal on the surfaces of the entire Dnieper and of the Pripet and found every where that the more the upper parts of the convex banks project, that is the sharper the water is driven by them against the opposite concave banks the greater is the depth on the neighbouring points of inflexion.

In natural non-consolidated beds the spring current being directed with great speed on the tongues of sand forms frequently at the convexities of the bancs convergent watersthreads which excavate the bank and cause, on the sandy ridges near the banks, longitudinal holes with a gulf or a lake-like form. Such a hollowing out of the convex bank is always accompanied with a reduction of depth on the inflexions of the bed and in time projections are formed which are a hindrance to navigation. From the point at which the concave bank ceases to intersect the upper current, the convergence of the water lessens and a dimunation of the depths of the channel results.

In proportion as the bank diviates from the general direction of the bed, the angle of convergence of the water-threads lessens and finally instead of converging, they diverge. At this place the longitudinal channel of the bed is replaced by a superficial wave-formed bed, the depth of which diminishes by degrees; the channel ceases to be the meeting-place of the converging water-threads and the muddy bottom-stream rises to the surface of the water.

The characteristic phenomena of convergence of water-threads in an under current, and the principals of their divergences near the junction of the two opposite curves of the bed, may be followed on several plans made in accordance with our investigations ou the Dnieper at Kief. These plans are not shown here in order not to burden the report with a too great number of supplements.

At the cessation of the convergent position of the water-threads, the fan-shaped bottom currents reach the surface which then presents a boiling appearance caused by impulsive local rising and falling back of the threads. The displacement of alluvion is no longer effected directly but in zig-zag lines and in the ridges of the sandbanks in a slanting direction. Banks disappear and are replaced by others and in this way the bottom movement continues and the banks moves down-stream. If the water flowing on the banks met with no hindrances in its course, this movement of alluvion would be continual as is seen in the deltas of sea-mouths.

In river-beds such an incessant descent cannot take place for at a short distance from the ridge the water strikes against the bank of the river, whereby the further removal of the bank is prevented. The ridge of each submarine tongue at an inflexion of the bed unites the two banks, consequently the place of its tangent with the bank which is left by the water is always situated much lower down-stream as the point of the tangent of the ridge which meets the bank towards which the current flows. (See design 3, Plate II).

On this plan the tangent point *A* on the ridge with the left bank is much farther up stream than the tangent point *B* with the right bank. The water flowing over the ridge at point *A* strikes against the bank and springing back encounters the neighbouring water-threads, forming a convergence of water; which are strengthened by the additional stream of water-threads flowing from the right towards the concave bank.

By this convergence the extremity of the ridge is washed away, thus a certain limit only is allowed to descend.

In consequence of the increase in the mass of the converging water-threads, the power of their flow down stream is augmented and at the same time the distance of the summit of the ridge from the concave bank becomes greater.

We know that the ridges in spite of the resistance offered by the bank move farther downstream as the water becomes smoother. This has two causes, first the excavation of the concave bank and second the reduction of the power of convergence with the decrease of flow of water in the river.

If the curve of the left bank be sharp and long, so that is forms itself a convergent current, as shown on the plan a deepness will arise. If the insufficiently developed curve of the concave bank cannot keep the convergence of the water, a divergence to the right will result. If the right bank is at some distance the diverging water meeting with no resistance diverges in different directions oblique to one another.

In consequence of the deviation of the stream in different directions the river becomes divided into several single currents, which often become independent arms.

The wider the bed the easier is the formation of new currents and the developement of these into separate arms.

Generally, rivers which flow through meadows have the greatest tendency to divide into separate arms, whereas rivers with high banks never divide into more than two arms and that only at places where the bed becomes wider. (See design 4).

In consequence of the divergence of the water at the widening of the bed a tongue of land is formed, which if the bed is straight is placed in a slightly convex form towards the lower part of the stream in a line nearly normal to the banks. This convexity continually increases in consequence of the excavation of the banks produced by the water flowing from the top of the ridge. The longer the tongue of land, and the smoother the water, the nearer become the water-threads to a direction normal to the banks, in consequence of which the excavation and the widening of the bed is increased.

The spring water advancing with great power of inertia on the central part of the tongue of earth brings with it a mass of alluvion, so that in time an island is formed, the height of which increases from one end to the other.

The difference between such a shallow or island and the shallow of a river flowing in meadow grounds, (see Plate II). is that the first has nearly always two submarine tongues, one at the beginning and the other at the end of each arm; the second has only one submarine tongue, or when the bank is very irregular an indefinite number of them.

The force of convergence is proportional to the active power of the moving water, therefore the united water-threads can keep on banks which are but slightly concave and at spring-tides even on convex banks when all the water-threads flow against all the sandy shallows.

At low spring-tides the convergent current is limited to the concave parts of the banks and a larger concavity is always required to retain the line of the axis of the converging current directed along the channel.

Accidental elevations on the submarine tongues of land may cause separation and divergence of the water-threads and even the formation of isolated currents.

On one of the attached plans (Plate II) are seen six dotted lines; these indicate the direction of the axes of the converging currents at the deep places and the most important depths above the elevations of the bed. The numbers I to VI correspond to the gradual lowering of the level of the water.

Based on combinations confirmed by direct measurements we have presented on Plate II, design 3 six longitudinal profiles of the water surface in the direction of the dotted axis-lines corresponding to the gradually descending levels of water.

The increase of the superficial speed of the current and of the longitudinal slope of the water depends on the angmentation of the divergence of the water-threads, that is the flow of the water towards the wider parts of the bed. When the sandy tongues are submerged at high-water the middle parts of the deep places form eddies which extend to the extremities of the elevation.

The divergence of the threads of the Spring-water begins at the point where the distance between the summits of the ridges commences to increase and near the point where the concavity of the bank ceases. (Point *B* on the plan).

The divergence of the threads of the Spring water induces a descent of the water-level below the shallows, which extending a little upstream increases the slope of the lower part of the deep channels of the river.

The convergence of the threads of the Spring water resulting from the lessening of the distance between the summits of the banks, begins about the middle of the shallows. The diminution of slope hereby caused extending over the entire sand-bank, gradually increases the current in descending to the middle of the deep part. The longitudinal profile resulting herefrom has in the depths a concave form.

After the high-water has flown off and the Sandy tongues of land are dry the current encounters an obstacle formed by the masses of soil brought down by the spring water and deposited on the upper part of the shallow.

The sandy alluvion of the upper part of the stream gradually disappears under the influence of the bottom current and re-appears at the lower end of the shallow, where at the same time the fall of the water is considerably concentrated.

In consequence of the drying of the deposits of sand, the point of division of the water-threads descends more and more down stream; therefore, the slopes below the deep parts and above the elevations are lessened. The diminution of the slope at this part is caused also by eddies, which are the result of the accumulation of alluvion at the lower part of the shallows. On the shallow, and particularly on the summit of the tongues of land, there is a strong fall of water, the sleepness of which increases with the lowering of the level of the water; the pôsition of this fall on the longitudinal section moves forward against the stream. So that, as the water lowers. the longitudinal profile of the shallow from being concave becomes gradually convex. The point of the strongest fall changes quickly after, the tongues of land become dry. It passes suddenly from below a deep part to a place below a shallow, then with a further lowering of the water it goes upstream, within the limits of the summit of the submarine tongue of land.

The deposit of alluvion on the shallows is caused by the water at high tide extending over the tongues of land; the deposit diminishes as the level of the water is lowered, which results from the tongues laid dry diverting the water-threads towards the middle of the bed and thus causing a narrowing of the angle of their divergence.

At the beginning of this movement, when the mass of water has sufficient power to displace large quantities of sand, the latter advance from the upper part of the shallows in the direction of the greatest speed towards lower part of the tongue oı land (on our drawing on the right bank near the point B). The increase of the summit of the submarine tongue at the point indicated serves to turn the water in another direction (to the left) adding on one side to the curve of the channel and on the other side to its depth and to the intersection of the upper part of the submarine tongue. To this cause must be attributed the well-known phenomena of the deepening of shallows with a lowering of the level of the water.

After examining the direction of the fluvial currents, resulting from the configuration of the ridges of the banks and the influence of these currents on the form of the bed, we can determine with precision the form of bank which corresponds best with the requirements af navigation and assists to the formation of a deep and constant channel.

We have already seen that in order to keep the converging current of the channel on the concave bank, the latter must have a sufficiently developed and continuous curve. Therefore the naturel parts must be provided with a

dressing, projections must be cut down and hollows covered by regulating dikes, connected by transversel planks with the bank, the object of which is to prevent the water threads at high tide extending across the dike and forming behind at a converging current capable of excavating the bank and increasing the dimensions of the hollows.

There is no converging current at the inflexions of the bed; there are, so to speak, not even banks, for at these parts the bed being placed at nearly a right angle to the tops of the banks is limited on one side by the parts of the river downstream and on the other by those upstream. In order to form in the inflexions of the bed a longitudinal cavity, durable and of sufficient depth it is necessary to have a converging current and for this purpose, taking as a basis the combinations which we have shown, we must create an artificial bank, the direction of which must always intersect the flowing threads; therefore, the banks should always be so constructed that the tangents of their curves form at every point angles with the direction of the converging current. The concave bank must have, as far as possibe, a concave form, but it may have a certain convexity at the place where, projecting into the bed, it intersects the direction of the threads. The length of the artificial bank should be so fixed that the converging current directed by it, not expanding at low-water may reach the concavity of the opposite bank, where the water having flown off the rongue of earth has already formed a converging current. As the extremety of the artificial bank is intended to direct the threads at low-water, the height of the bank at this part should be as little as possible, in order not to provoke a superfluous eddy at high water. The foot of the artificial bank, if it is submerged, should be constructed in masonry up to the top of the bank, and when it is not under water to the highest water-level. In order to join easely the artificial with the natural bank, the foot of the first must be in masonry at the part where the concavity decreases. As the object of the artificial bank is to prevent the water flowing off on one side, to form a convergence of the water-threads, and to retnrn them near to it, a suitable style of regulation must be selected and a proper position and profile given to it. To retain the current of the channel along the bank the most suitable system is found to the groins laid slantingly with their top against the current; as the water-threads not only follow the shape of the tops but endeavour to cross over them and wet each head on both sides.

The upper part of the artificial bank wich serves to throw back the spring water-threads from the convexity of the natural bank can be best preserved from excavation by the construction of a longitudinal dike attached by transverse work to the bank.

Sharp sloping banks contribute to the retention of a convergent current along the banks, while slight slopes induce divergence of the water-threads and the formation of a bottom current; for this reason, it is necessary to give a sharp slope to the heads of the groins laid along the converging current.

In an arrangement with fascines on the Dnieper and on the Pripet at

summer low-water wo gave the part oi the heads above water an incline almost vertical and placed the fascines with their thick ends upwards.

This arrangement of the upper part of the heads of the groins is of great service in preventing as much as possible injury to the fascine work by the number of enormous floats which drift about without any order. If the slope of the heads be steep the converging stream directed downwards hollows out the bottom to a great extent; to prevent this a layer of facines of large dimensions is placed under the heads, so that deep excavations cannot occur.

Danger of collision from vessels is less when the bank is steep, than when it is at a soft incline. Notwithstanding the active navigation both by day and by night on the comparatively small channel of the Pripet it has, up to the present never happened that a steamer or any other vessel has run againt the heads on the concave bank. This is due to the fact that the converging current allong the steep bank carries the vessel away from the bank and prevents any collision, even if the distance of the vessel from the bank be small. A configuration of the bank in a soft incline would cause the water-threads to drive against the banks, and the vessel would run aground.

The bottom ends of the groins may be unbedded in the sand-banks, but in order to prevent to hollowing out of the tongues of land by the spring current, the bottom ends of the groins must be prolonged to the bank and arranged perpendicularly to the convex bank. They will form a curve as shown on Sketch 3, Plate II and their height should correspond with the height of the projected bank, gradually diminishing as it descends the current.

It cannot be doubted that with a configuration of converging bank as represented on Sketch 3, Plate II a deep cavity is formed in the length of the river-bed, its depth will, however, be less than the depth of the two united current situated lower downstream, so that the form of the bank does not provide a complete equalisation of depths. In order to lessen the depth at the parts mentioned of the concave bank and at the same time to protect the foundation from being hollowed out by the concentrated current, erections, as shown by dotted lines in the plan may be applied, giving them a downstream direction, and thus change the converging current which is directed downstream into a diverging one which tends upwards. In thus profiting of the bottom elevations there is no danger of an increase of the hollowing of banks, for the depths forming in the bottom beyond the elevations are of but small width. The soil which is hollowed out is carried away by the diverging threads. and heaped up at the foot of the bank, giving it a slight incline.

In reviewing the measures to be taken in the construction of a projected bank, it may be accepted as a rule that it is advisable to lengthen the concave banks and to advance the convex extremities ln the bed; the projection of the upper part of the convex bank should be developed as much as possible.

There is no fear of any danger arising from the retention of the water by the artificial bank, as the height of the bank does nos exceed that of the elevation situated lower downstream in the direction D E (Plate II). An eddy of the spring waters is formed above the shallows and the eddies in the depths are proportionately diminished, so that the lower concave section of the high tides approaches the natural straight configuration, and the slope and the surface speed become more regular. After the excavation of the submarine sandy reach along artificial bank, the eddy of the summer water will diminish, the surface will extent upstream over the lower part of a depth and downstream over the upper part of another depth. Nevertheless, the surface of the summer water concentrates, itself at the sharp curve of the banks, as this causes a strong eddy. This concentration of the slope on the deepened shoals preserves the neightbouring depths from the undesirable transference upon them of the fall of the water, which often occurs in the application of the system of retaining the water for the regulation of the bed.

The rule laid down for the advancement of the extremities of concave banks in the bed has been practically applied in the regulation of the bed of the Pripet, as we have shown in a previous report to the assembly of Russian hydrostatical Engineers. Primitively, the width given to the projected bed of the Pripet was the considerable one of 200 m., and for the execution of the work groins were built on each bank. These works were done in 1884 and 1885. But the parts of the least depth moved from the shallows to the curves of the bed. This result is inevitable, for, after the narrowing of the bed, when the direction of the banks is divergent a divergence of threads and a deposit of alluvion always ensues. Therefore it was necessary to narrow the bed gradually up to the concavities by advancing the groins; and this explains why the lengthening of the groins situated above the concave bank has no influence on the deepening of the shallows; whereas the advancement of the groins at the extremity of the opposite bank produces at once a deepening of the channel and constancy in its position, especially as the number of bottom elevations is increased by the construction of intermediate groins.

The correctness of the rule has also been confirmed by the construction of groins on the Dnieper above Kiev, where in order to deepen the entrance to the port of the town it was found necessary to advance considerably the extremity of the slightly concave left bank into the bed. The shape of bank and the position of the groins as represented on Plate II have been applied to the regulation of the Pripet on the sandbank Proghnoïski, to which, however, so much developement has not been given on the converging bank in order to avoid the expensive powerful strengthening of the opposite bank, for which a considerable depth was not necessary.

After the configurations described had been made in the course of the Pripet near Tschernobyl on four sand-banks, the depth at the inflexions of the canal was 1.5 times more than was desired if the summer water-level be taken as a basis. No unfavourable results to the neighbouring parts were

caused, for a great part of the slope remained on the regulated reach, and this on account of the eddies formed by the projections of the banks.

It is also, to be observed that these projections are far from being developed to the extent shown on Plate II; therefore, if a later deepening of the bed became necessary, the convergence of the water could be strengthened by strengthening the basis of the opposite banks. Thus the explanation given of the positions of fluvial currents is quite confirmed by the data obtained in practice, the manifestation of which preceded the theoretical explanation and gave cause to examinations, observations and generalisation of the subject.

In order to have a considerable and stable deepening of the bed it is necessary to give to the concave bank a regular form and a sufficient curve, and by an artifial lengthening to conduct the water to the concavity of the opposite bank, which has to be treated in the same manner. With this the inflexions of the bed disappear and we obtain banks alternatively concave on each side.

These banks may be designated conductors of the converging water-threads and of the channel.

Up to the present we have spoken of concave banks, by the development of which the inflexions of the bed can be obviated. The formation of such banks is the principal means of regulating the current in the interests of steam navigation; we must, however, also consider the opposite lying banks against which the bottom current flows. The bottom current rising on the slight slopes reaches the upper beds of water and is transformed into an upper current, which with the threads converging towards the channel forms a channel-current near the concave banks. In view of the transformation of bottom-current into an upper-current, care must be taken that the water diverges proportionately along the convex bank, so that the divergence arises of the threads from the channel which is winding and of diminishing depth.

A particular obstacle to the uniforme divergence of water along slightly sloping banks is the side-arms by which the bottom current flows away, depriving the principal converging current of its threads, and, thus, diminishing the convergence of the water towards the channel; in consequence of which may be caused a divergence in the channel and even its entire cessation.

The sanding of the arms has often been observed; this is a consequence of the phenomenon described and is the reason why the side-arms should be closed.

By these arms we understand those of which the direction, when they separate from the principal bed, does not accord with the direction of its current, flows into a side arm and is then changed into a converging current near to one of the banks.

Besides the side-arms in the banks the transformation of the bottom current into an upper current arises from the increase in the slight slope of the convex bank, when the bottom current, flowing to a considerable distance from the

channel ceases to supply it to a sufficient degree with converging threads, from which results a diminution of convergence, increase of the distance of the channel from the concave bank, divergence of the upper water-threads and a deposit of alluvion. This phenomenon is principally observed on the shallows at widenings of the bed.

Even a considerable narrowing of the bed at these parts produces no improvement and the channel has neither the desired depth nor a permanent position. That is because artificial narrowing iufluences the consequence and not the cause. The widening of the bed is not the primitive cause of the sanding and instability of the channel; the cause is the irregular distribution of the currents of the river. In narrowing the bed by advancing the two banks converging currents are created on each bank and the channel cannot possibly maintain a durable position near to one of them, and so flows in irrugular curves from one bank to the other under the influence of the changes taking place on the neighbouring parts of the river and the rising and falling of the water-level.

Parallel, or nearly parallel lines look very well on the plan, but are in reality not applicable, as the idea on which they are based is in contradiction to the laws of movements of currents in rivers. According to plans of regulation works executed or several foreign rivers it is seen that in these the channel deviates systemattically from the position expected, that the windings of the channel are arbitrary and temporary, that the channel often extends to the convex banks and the concavities are covered with alluvion in the form of moving tongues of land.

These consequences of the applicatiou of the system of hydraulic obstruction on the shallows will be understood if we examine the influence which the elevations advancing from the extremity of the convex bank has on the bottom current. The bottom current reaching the heads of the groins cannot turn towards the concave bank, but is inevitably changed into a converging current descending towards the bottom, rushing towards the elevations and excavating holes in them. Then becoming again a bottom current it diverges, carrying the excavated soil into the channel, which in this way is not only not deepened, but may become sanded up. The groins confining the width of the diverging current in a fan-like form can only increase the flow of water towards the channel at a certain distance downstream; they must therefore not be constructed near tö the tops of the submarine tongues, but are of much more use when situated at the commencement of the shallows. The arrangement and the profile of the groins near the convex bank must be quite different to the extremity of the concave bank, for their purpose is not to attract the current of the channel, but on the contrary to direct it towards the opposite bank, and, in particular, to reduce the angle of divergence of the threads of the bottom current, so that it can be sooner changed into an upper current, which increases the divergence near the tops of the tongues. For this reason these groins must be inclined downstream, their extremities directed

against the current and their slope very slight. The arrangement of the groins near the tongues downstream, just where a diminution of convergence is desirable, in order to prevent the excavation of the bottom towards the concave bank.

However, in order to utilise the watér-threads and to return them more quickly to the channel, submerged works may be erected on the convex bank, parallel to the bank. (Similar to those shown on Plate II).

It is to be supposed that such works in changing the longitudinal direction of the bottom current into a transverse one may accelerate the transformation of this current of upper water-threads into a current directed towards the channel.

In a natural bed the convergence and divergence of the water are unequal. In the depths we observe a converging current and on shallows of great extent a diverging current. The tendency of the regulation of the bed should be to promote a proportionate partition of these currents along the river, to accomplish which the current should be directed by a suitable construction of the banks, in such way that a converging and a diverging current is obtained in every transverse profile It is in the interests of navigation to have a converging current all along the river, and, for this reason great care should be taken in transforming the diverging currents on extensive elevations into converging currents; but, it is also necessary to attend to the conformitv of the divergence of the bottom current by reducing as required the angles of the divergence of the threads, as will as to the increase or their divergence in the depths in causing submerged erections.

Narrowing of the bed is of no use and is only the consequence of the advancing of the guiding bank in the bed on the shoals themselves, and of the concave bank above the shoals.

The theory exposed concerning the directions of river currents and the rules which have been deduced for the rational regulation of rivers are founded on observations on the effect of regulating works, observations on the movement of floats and, generally on any Objects floating on the water, on examinations of the forms of river-beds and on the transference of alluvion. A part of these observations has confirmed the correctness of the rules deduced; and the results gathered by means of the formulae of dynamics likewise prove the exactitude of the theory. Nevertheless, for the developement of this scientific theory in the interests of regulation works and in order to obtain principles which are exactly in accordance with reality for the mathematical treatment of hydrodynamics, it is requisite that future observations on the directions and positions of water-threads be more exact. Up to the present such observations could not be made for want of suitable instruments. We must consider that it has hitherto been impossible to determine exactly the direction of a current even in an upper bed of water, since the direction of the movement of a float is, as explained above, not in exact accordance with the direction of the water-threads. Therefore, in order to become an exact science, hydraulics demands instruments by which the direc-

tion of the movement of water at all points of the transverse section of the bed may be determined.

To determine the direction of the wind a fane or weathercock is used, and a similar apparatus may also serve for the direction of water-threads; still, the construction of such an instrument for use in water must be of a much more complicated nature, than that of an aerial fane, and the observation of the water-threads much more difficult. The aerial fane indicates the direction of the wind in an horizontal surface while a submarine fane must show the direction of the movement of the water at the same time horizontally and vertically. The deviations in the directions of water-threads are made slowly and are weak, it is, therefore, necessary that the instrument of measurement be very sensitive and exact. The principal difficulty is, however, the fixing and arrangement of the submarine apparatus and the observation of its indications. However securely a vessel may be layed to with anchors and ropes, there always exists some swinging and rotative motion, which is the result of the force of the current, of the wind or even caused by the moving about of the people on board. For this reason the placing and using of the apparatus on a boat would afford inexact and even quite erroneous results. It is impossible to take direct observations of the movement of the submarine fane. The use of instruments for the transmission of the movements is however difficult, because they hinder the free working of the fane and reduce its sensitiveness.

These observations show that such an apparatus must not but of ordinary construction, but must, to answer its purpose be of a very complicated nature.

Researches made by a submarine fane should be executed, as far as possible, on an extensive scale, in order that exact deductions may be made from the observations taken, leaving on one side accidental influences, which often so complicate the phenomenon observed that it seems to be at first sight out of all rule and subject to no definite laws.

Thus, for example, in order make clear the two kinds of currents in the fluvial bed we have said that a part of the section is occupied by converging and the other part by bottom or divergent water-threads. In reality, however, it may happen that a convergence appears at several places and a divergence may exist not only at two points, but at many points of a section.

In order to discover the causes of these complications we must examine them with exactitude and in detail by means of repeated measurements at points near to one another and on several adjacent transverse sections of the bed.

For the execution of such examinations the writer of the present report has projected two submarine fanes, one of wich is complete, and is found to be quite suitable for its purpose. Designs of it are attached (See Plates VI, VII, and VIII). It is composed of two steel arms A A, perpendicular to each other, fixed across a steel rod F, which moves vertically, as well as horizontally. To equalise the wings of the fane a leaden weight B in the form of a cone is placed at the other extremity of the rod.

A brass tube T serves as axis for the horizontal movement, with a conical steel stop D at its lower end. The axis for the vertical movement passes through the diameter E of this tube. The inner axis of the rests in a supporting steel socket S, fixed inside a brase ring Z. The ring Z is screwed into the lower end of the iron tube U, which serves as base for all the apparatus. The brass tube passes through the centre of this supporting tube, so that the geometrical axes of both agree. To the upper part of the principal tube, as also to its lower part a bronze arch I is screwed at the upper extremity of which is a steel screw with a point and K supporting the upper part of the middle tube.

Such a submarine fane gives the movement of a water-thread in horizontal as well as in vertical diretions. The needle A shows the horizontal deviation. This needle is fixed to the centre tube and to the index M on the principal tube. The water-thread having turned the wing of the the fane to the right or to thė left, turns the middle tube and consequently the needle, which shows on the index the extent of the angle of deviation of the thread. By means of the rod H and the index O, the needle indicates the vertical deviations of the threads. Both of these parts of the apparatus are fixed on the middele tube; the needle moves on the axis and the index is immovable. The vertical movements of the fane are transmitted to the needle by two brass wires N N of equal length running parallel to one another from the bend of the rod of the fane to the needle. The correction and extension of the brass wires is effected by means of screw-couplings P P.

For placing the fane at the desired depth the principal tube is marked out in centimeters in colours.

To set the apparatus according to the profile designated by the indicators on the bank pinules C are used attached to the side of the upper part, and for placing it vertically a level G is employed which is fixed on a horizontal index.

The entire length of the apparatus is about 6 m., so that it can be placed in the water to a depth of 5 m.

For placing the fane we take a support with three legs which carries a rectangular frame of hollow iron tubes, and is made of oak or other heavy, solid wood. The supporting table has iron plates at its sides, with projecting ends which serve as holes for the feet. The feet are coated at the sides on all their length with iron and are fixed in the holes by means of compressing screws a a a. To prevent the feet sinking in the soft ground small iron cups S S S are fixed at their extremities. These cups resting on their sharp edges prevent the supports from slipping on stony soil. In order that the supports may not separate from each other more than is desirable they are joined at about half their height by ropes b b b. The ends of these ropes are free, so thet when the apparatus is placed in the water they may be pulled or slackened as required for the alteration of the position of the feet.

The frame by means of which the fane is let down is fixed on the upper

part of the support by means of a double hinge *r* so that it can move freely. On the principal frame a small frame *d* moves up and down on rollers. This small frame has two cramp-irons *e e*. A similar cramp-irion is placed on the upper part of the principal frame *g*. The tube of the fane is placed in these three cramp-irons. To keep the tube in a vertical position three tin cords *z z z* issue from the lower part of the frame, each of which passes over the pullies *u* at the end of the supporting feet, passing thence upwards along the foot towards the winders and ratchet-wheels *i i i*. By winding up or unwinding these three cords the fane is kept in a vertical position.

For raising and for letting down the fane a cord *k* is used issuing from the frame *d*, which turns with the apparatus. The card passes over the pulley A which is fixed to the upper part of the large frame to the winder *H*.

For observations to be made in one single place at different depths it is not necessary to rearrange the pinules each time an observation be taken, as the tube of the fane can be fixed to the cramping-irons *e e* by the screws *n n* at the commencement of the observations.

In order to give greater wheight to the apparatus, with the view of obtaining greater fixety, a cylindrical iron reservoir *p* is suspended by a pulley in the middle of the upper plate and underneath it. This reservoir can be filled with water and emplied by means of an opening and a valve.

For the transport and fixing of the fane and the supports two boats are required, fitted with scaffolding as seen on the sketch. Scaffolding of 3.5 m. in height is sufficient to lift the supports out of the water. The lifting and lowering is effected by means of a small windlass or capstan placed on the bridge at the after part of the boat. Moveable platforms at each side of the apparatus serve as standing places for the observers and are so elevated as to be always near the upper end of the tube and in view of the indices, The same windlass or capstan which works the apparatus also raises the platforms. For this purpose are attached to the principal cable at point *B* two side cables, which travel together over a fixed pulley *T* with three wheels, placed at the top of the scaffold, thence under the pulleys *D D*, over the pulleys *E E* and then descend to the platform.

For lifting and laying out the anchors a small boat is required. The arrangement of the boats is shown on the plan.

With the aid of this apparatus measurement was effected in the months of September and October 1893 of the direction of water-threads on the Dnieper at Jekaterinoslaw.

The results of these observations are embodied in a special report.

Inscriptions des Planches.	Inschriften der Zeichnungen.	Description of the Plates.
PLANCHE I.	BLATT I.	PLATE I.
Les courants divergent.	Die Strömungen laufen auseinander.	The currents diverge.
„ „ convergent.	„ „ „ zusammen.	„ „ converge.
PLANCHE II.	BLATT II.	PLATE II.
Vert.	Grün.	Green.
Jaune.	Gelb.	Yellow.
Rose.	Rosa.	Rose.
Rouge.	Roth.	Red.
Façade.	Aufriss.	Elevation.
Profils longitudinaux.	Längsprofile.	Longitudinal sections.
Mouille.	Tiefes Wasser.	Deep water.
Banc de sable.	Sandbank.	Sand-bank.
A un niveau élevé de printemps.	Bei hohem Frühjahrswasser.	High spring level.
A un bas niveau de printemps.	„ niedrigem „	Low „ „
A un niveau élevé d'été.	„ hohem Sommerwasser.	High summer „
Au niveau d'étiage.	„ niedrigstem „	Low-water level.
A un niveau bas.	„ niedrigem Wasserstande.	At a low level.
Au niveau d'eau le plus bas.	„ dem niedrigsten „	At lowest level.
PLANCHE III.	BLATT III.	PLATE III.
Embouchure du bras	Mündung des Armes.	Mouth of the branch stream . . . .
Embouchure du golfe et au printemps du torrent Starik.	Mündung des Golfes und im Frühling des Wildstromes Starik.	Mouth of the gulf and rapids of Starik in spring.
Digue conductrice des fils d'eau.	Leitdämme für die Strömung.	Dike regulating the current.
Culée fluviale.	Flusspfeiler.	Abutment in the river.
„ du bord.	Landpfeiler.	„ on shore.
Quai.	Uferdamm.	Wharf.
Culée riveraine.	Landpfeiler.	Abutment on the bank.
Les inscriptions sur les profils des plans . . . désignent le nombre de minutes écoulées du départ des flotteurs du premier profil.	Die Inschriften auf den Profilen der Pläne . . . geben die Anzahl der Minuten an, welche seit Abgang der Schwimmer des ersten Profiles verstrichen sind.	The references in the sections of the projections . . . . indicate the number of minutes spent from the departure of the floats of the first section.
Les inscriptions sur les profils des vitesses désignent la vitesse en sagènes en une seconde.	Die Inschriften auf den Geschwindigkeitsprofilen geben die Geschwindigkeit in Saschenen per Sekunde an.	The references on the sections showing the speed indicate the speed in *sagènes* per second.
Signes conventionnels.	Zeichenerklärung.	Conventional signs.

LELIAVSKI.

PLANCHE IV.

Plan de disposition des ondes sur le Dniépre à Kief dressé selon les recherches faites en Avril 1892, à un niveau + 1,09 Sagène de la tringle de l'hydromètre du pont suspendu.

Profils des vitesses.

Limite naturelle de Natalka.

Voies des flotteurs.

Crue de l'eau au niveau du printemps.

Démarcation à un niveau bas.

Crête du bord.

Direction de la rotation des flotteurs, les chiffres marquent le nombre de tours entre les deux profils voisins.

Travaux couverts d'eau.

Flotteur au diamètre de . . . .

Les chiffres sur les profils des vitesses marquent la vitesse des flotteurs en sagènes en une seconde.

BLATT IV.

Darstellung der Wellenbewegung auf dem Dnjepr bei Kiew, aufgenommen nach im April 1892 bei einem Wasserstande von + 1,09 Saschene am Hydrometer der Hängebrücke angestellten Beobachtungen.

Geschwindigkeitsprofile.

Natürliche Grenze von Natalka.

Weg der Schwimmer.

Hochwasser im Frühjahr.

Begrenzung bei niedrigem Wasserstande.

Uferkamm.

Richtung der Drehung der Schwimmer, die Ziffern geben die Anzahl der Umdrehungen zwischen zwei benachbarten Profilen an.

Kunstbauten unter Wasser.

Schwimmer mit einem Durchmesser von . . . .

Die Zahlen auf den Geschwindigkeitsprofilen geben die Geschwindigkeit der Schwimmer in Saschenen per Sekunde an.

PLATE IV.

Projection of the state of the waves on the Dnieper at Kiev drawn up from investigations made in April 1892, at a level of 1.09 *sagène* above the rod of the hydrometer of the suspension bridge.

Sections showing the speed.

Natural limit of Natalka.

Ways taken by the floats.

Water-level during spring floods.

Limit at a low level.

Top of the bank.

Direction taken by the floats in rotation, the figures indicate the number of turns between the two neighbouring sections.

Works under water.

Float of a diameter of . . . .

The figures on the sections showing the speed mark the speed of the floats in *sagènes* per second.

PLANCHE V.

Plan de la direction des fils d'eau et profils de la direction des flotteurs à l'expiration d'intervalles de temps égaux.

Les chiffres sur les profils de direction des flotteurs marquent les minutes écoulées depuis le départ à partir du premier.

(Pour les autres inscriptions, voir les traductions „Planche IV".)

BLATT V.

Richtung der Strömung und Profile der Richtung der Schwimmer nach Verlauf gleichmässiger Zeitintervallen.

Die Ziffern auf den Profilen der Richtung der Schwimmer geben die Anzahl der Minuten an, welche seit Abgang des ersten verflossen sind.

(Die übrigen Inschriften siehe Uebersetzung zu Blatt IV.)

PLATE V.

Projection of the direction of the current and sections of the direction taken by the floats at regular intervals.

The figures on the sections showing the direction taken by the floats mark the minutes that elapse after the departure of the first.

(For other references see translations under Plate IV.)

PLANCHE VI.

Dessin de la girouette sous-marine, ½ de la grandeur naturelle.

Section de l'extrémité du tuyau par l'axe.

Vue de la partie postérieure.

Coupe par la ligne *a—b*.

BLATT VI.

Zeichnung des Strömungsanzeigers ½ der natürlichen Grösse.

Querschnitt des äussersten Röhrenendes durch die Achse.

Ansicht des hinteren Theiles.

Schnitt in der Linie *a—b*.

PLATE VI.

Sketch of the submarine vane, half actual size.

Section of the extremity of the tube made by the bed of the river.

Vue of the back.

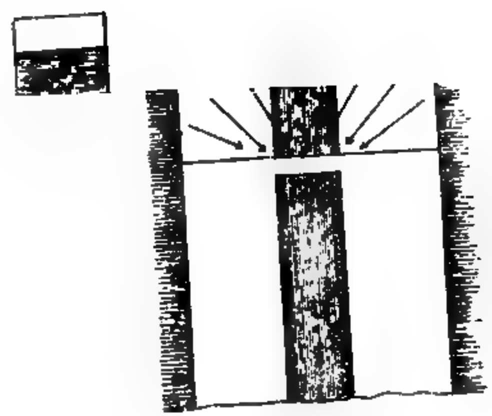
Section at the line *a—b*.

PLANCHE VII.	BLATT VII.	PLATE VII.
Elévation de côté.	Seitenansicht.	Elevation of the side.
Vue de devant.	Vorderansicht.	Front view.
Dessin du support de la girouette sous-marine.	Zeichnung des Ständers des Strömungsanzeigers.	Sketch of the support of the submarine fane.
Section du pied de support.	Querschnitt des Ständerfusses.	Section of the foot of the support.
Elévation de côté, 1/12 de la grandeur naturelle.	Seitenansicht 1/12 der natürlichen Grösse.	Elevation of the side 1/12 actual size.

PLANCHE VIII.	BLATT VIII.	PLATE VIII.
Dessin concernant le projet de la girouette sous-marine.	Zeichnung das Project eines Strömungsanzeigers betreffend.	Sketch relating to the project of the submarine fane.
Chaland et structure pour le transport et le posage de la girouette sous-marine.	Schute nebst Vorrichtung zum Transport und zur Aufstellung des Strömungsanzeigers.	Barge and arrangement for the transport and fixing in position of the submarine fane.
Plan schématique du posage du chaland par rapport aû jalon.	Skizze der Aufstellung der Schuten mit Hinsicht auf die Bake.	Projection of the scheme for the fixing in position of the stake.
Pin.	Tannenholz.	Pine.
Chêne.	Eichenholz.	Oak.
Fer.	Eisen.	Iron.
Fonte.	Gusseisen.	Cast-iron.
Vue de devant.	Vorderansicht.	

Inscriptions souvent répétées.	*Häufig wiederholte Ausdrücke.*	*Words frequently repeated.*
Bras.	Arm (eines Flusses).	Branch.
Dessin.	Zeichnung.	Sketch.
Pile.	Pfeiler.	Pile, pier.

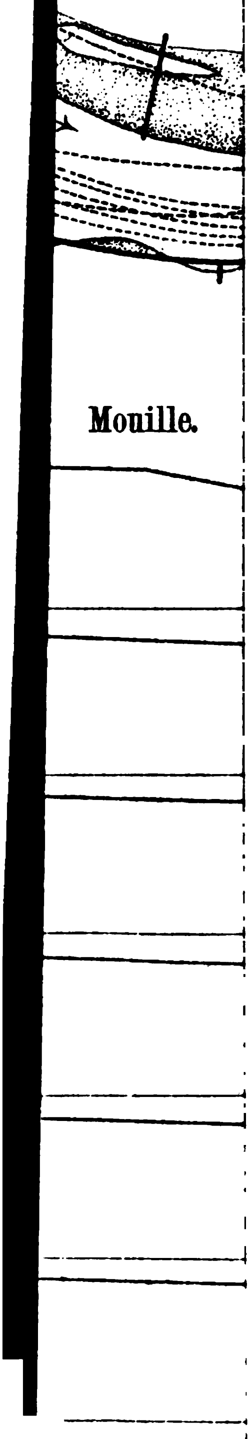
Mesures.	*Maasse.*	*Measures.*
1 sagène = 2,13 m. = 3 arsjines.	1 Saschene = 2,13 m. = 3 Arschinen.	1 sagène = 2.13 m. = 3 arsjines.
1 arsjine = 0,71 m. = 16 verchocs.	1 Arschine = 0,71 „ = 16 Werschok.	1 arsjine = 0.71 m. = 16 verchocs.
1 verchoc = 0.0444 m.	1 Werschok = 0,0444 m.	1 verchoc = 0.0444 m.

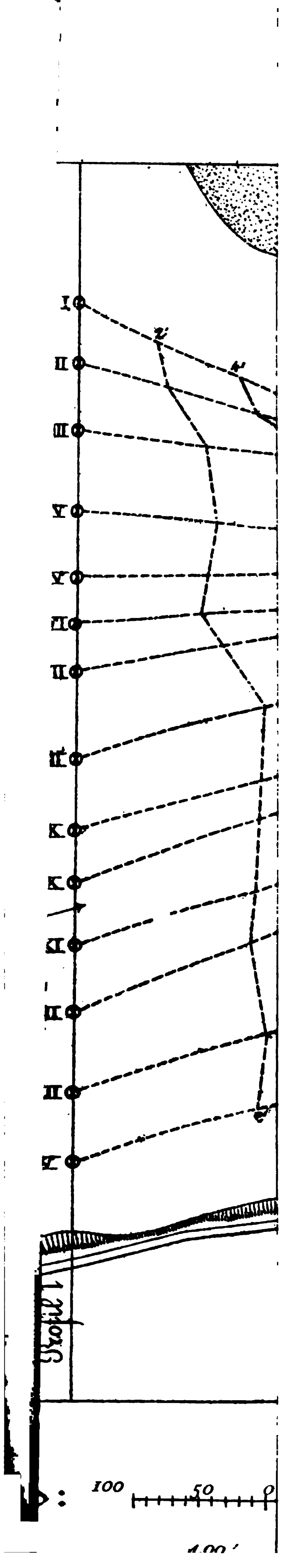


Les courants.

Les courants.

x et de l




Profil 1
100
50
0


Limite

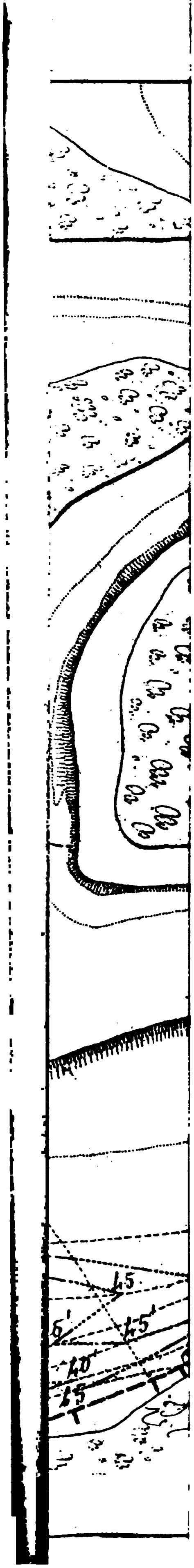
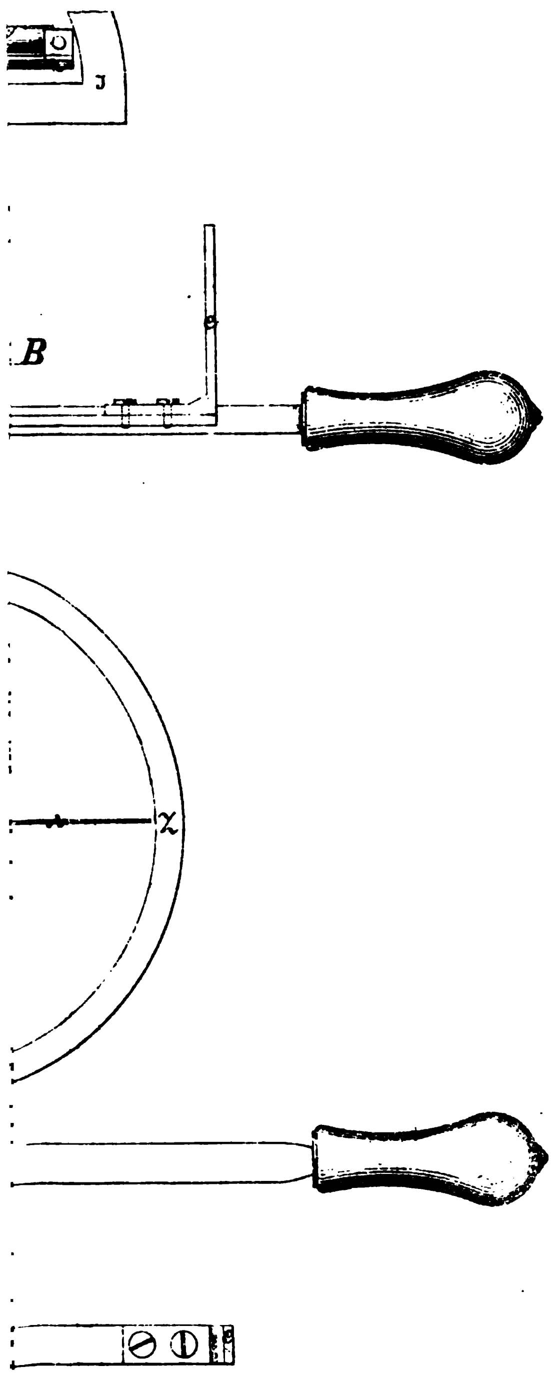
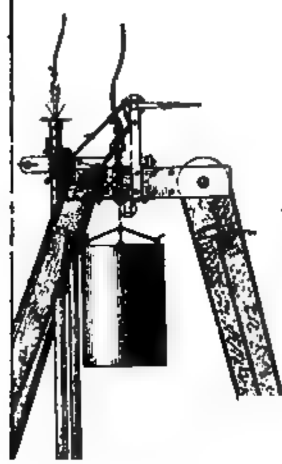


Planche N°. VI.

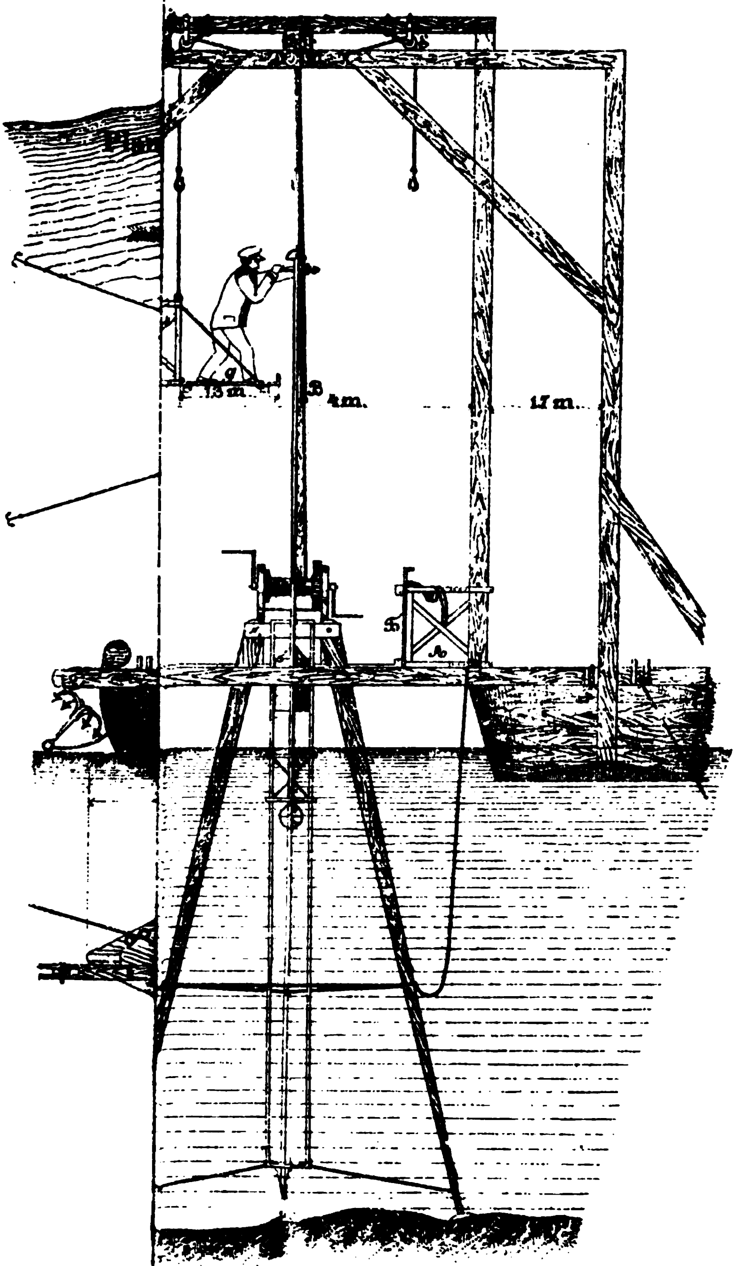


e la grandeur naturelle.



Elévation de côté.

1/36 de la grandeur naturelle.



$^1/_{60}$ de la grandeur naturelle.

Photolithogr, procédé

STEENDRUKKERIJ v/h. AMAND Amst.

29

VI[th] INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

6th QUESTION.

OBSERVATIONS

on the formation of the bottom of a river whose course is regulated by means of dams and dikes.

REPORT

BY

NIKOLAS MAKSIMOVITCH,
Ingénieur des voies de communication à Kiev.

THE HAGUE,
Printed by Belinfante B[ros], late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

VIth International Inland Navigation Congress.

THE HAGUE, 1894.

Observations on the formation of the bottom of a river whose course is regulated by means of dikes and dams.

REPORT

BY

NICOLAS MAKSIMOVITCH,

Ingénieur des voies de communication à Kiev.

The important question submitted to the 4th section of the sixth International Congress at the Hague, respecting the relation which exists between the form of rivers and the depth of their channels, demands in the first place a detailed and comparative study of the various forms of curves marking the banks of the bed that it is desired to regulate. In order to reply to this question it is necessary to have the means of studying experimentally, under conditions absolutely identical, the influence the form of the course has on the currents and the formation of the bottom, disregarding all secondary influences exercised to such an extent on every river in its natural state.

As regards the laying down of general rules and, with more reason, general principles applicable to the movement of a water-course, along a bank of a given form, the enormous mass of observations and facts furnished by the study of the disposition of currents in water-courses is not yet sufficient.

It is only by a general and complete study of all the conditions of the problem that we shall perhaps be able to throw some light upon this difficult question of hydraulics relating to rivers. Still, wherever regulating works have been carried out in rivers with changing bottoms, we possess same observations and have arrived at certain conclusions concerning the formation and position of bottoms with relation to the form of artificial banks.

In Russia which is so rich in water-courses and possesses the most

extensive river system in the whole continent of Europe, this natural wealth has long been neglected in consequence of the infatuation with which the building of railroads has been taken up, and it is only during the last twenty years that works for the regulation of Russian rivers and the improvement of their beds have been undertaken, and this has only been done in places where, when the water was low, shoals offered great difficulties to navigation.

For the last twelve years I have been entrusted with the management of the improvements of a section of one of the rivers in the south of Russia, viz. the Dnieper at Kiev. The works executed, in the course of which it has been necessary to resort to the use of dikes and dams for the regulation of the bed, have led me to form certain practical conclusions which in some degree bear upon the sixth question of the programme laid before the Congress and which I should like to impart to my colleagues abroad. Before making known the results of my observations it is indispensable to explain in general terms the *régime* of the Dnieper in the neighbourhood of Kiev.

The Dnieper is as regards length the second river in Europe; it takes its source in the centre of Russia, in the valleys situated south of the plateau of Waldai, where it issues from the small lake of Mehara, in the midst of the forests of the government of Smolensk. It flows from north to south, passes through the richest part of Russia and falls into the Black Sea.

The length of its course is 2262 kilometres; its basin includes the immense area of 616000 square kilometres with a population of 18 million inhabitants. The width of the Dnieper in its upper course does not exceed 80 m.; but after receiving several affluents it increases and attains an average breadth of 300 to 400 metres. Flowing towards the south it meets in the neighbourhood of Ekaterinoslav one of the spurs of the Carpathians, and, for a distance of 85 kilometres, is obstructed by a series of small cataracts or rapids which up to the present only rafts are able to pass. The improvement of this part of the stream is at present the object of special studies in the Ministry of Ways and Communications.

The most characteristic feature of the Dnieper is the extreme sinuosity of its course and the facility with which it changes the direction of its bed, the bottom and banks of which are for the most part sandy. The valley inundated by the Dnieper at the time of spring floods is very wide, in some places as much as 15 or 16 kilometres. In its ordinary state the bed is extremely capricious; there are places where it has changed its direction four times in the course of the last century. During the spring floods boats drawing as much as 2.60 m. can navigate upon it, while when the water is low, boats drawing at most 0.80 m. only are able to do so. The difference in level between the high and low water, measured

by a gauge, amounts to 7.25 metres. The incline of the bed varies between 0.00012 and 0.00008 m. and in cataracts it becomes 0.000385 m., the total fall being 190.90 metres.

The principal navigable affluents of the Dnieper are the Berezina, the Soy, the Pripet and the Desna. The Pripet is connected by canals with the Vistula and the Niemen, which both fall into the Baltic; finally the Berezina is in communication with the Western Dwina, which falls into the Gulf of Riga. This brief account shows the extreme commercial importance of the Dnieper and its basin. The total extent of water serviceable for rafts on the Dnieper and its affluents is almost 12.000 kilometres and that of the navigable way 5.900 kilometres. This river with its affluents embraces all the country between the Baltic and the Black Sea, uniting great commercial centres and meeting in its course with ten different railways.

The merchant fleet of the Dnieper is at present composed of 740 barges and boats and 165 steamboats and tugs, representing in tonnage a total of 180.000 tons.

The principal commercial ports and towns situated on the Dnieper are Kiev, Ekaterinoslav and Kherson.

The relation between the height of the water according to gauge marks and the corresponding discharge, determined by numerous measurements taken at Kiev, is represented approximately by the following parabola, Fig. 1.

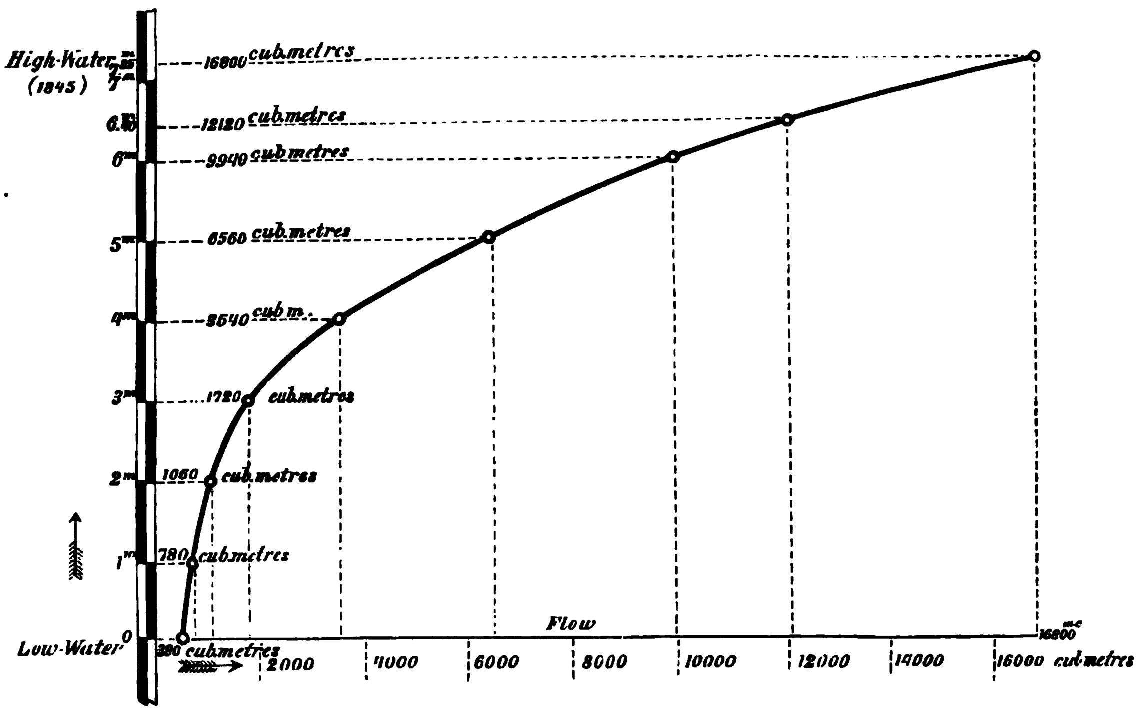


Fig. 1.

The figures on the left of the scale indicate the height of the water in metres, and the figures on the right above the horizontal dotted lines, which represent the abscissae of the parabola, indicate on a scale a thousand times smaller the corresponding discharge.

The total fall of the Dnieper from its source to its mouth in the Black Sea is 190.90 metres, which is distributed thus: 89.30 m. from the source to Kiev and 101.60 m. from Kiev to the mouth. The average incline is about 0.00008. The average velocity in the transverse section of the stream when the water is at a normal height is 0.50 m. per second; in the spring when the water is high it reaches 1.15 m.

The object of the regulating work, undertaken on the Dnieper at Kiev, is to rectify the irregularities of the current, which at this point divides into several branches, and to collect the ordinary waters into one common bed and give them the most advantageous direction, viz. along the quays of Kiev.

Fig. 2. represents the plan of the scheme formed for the course of the Dnieper.

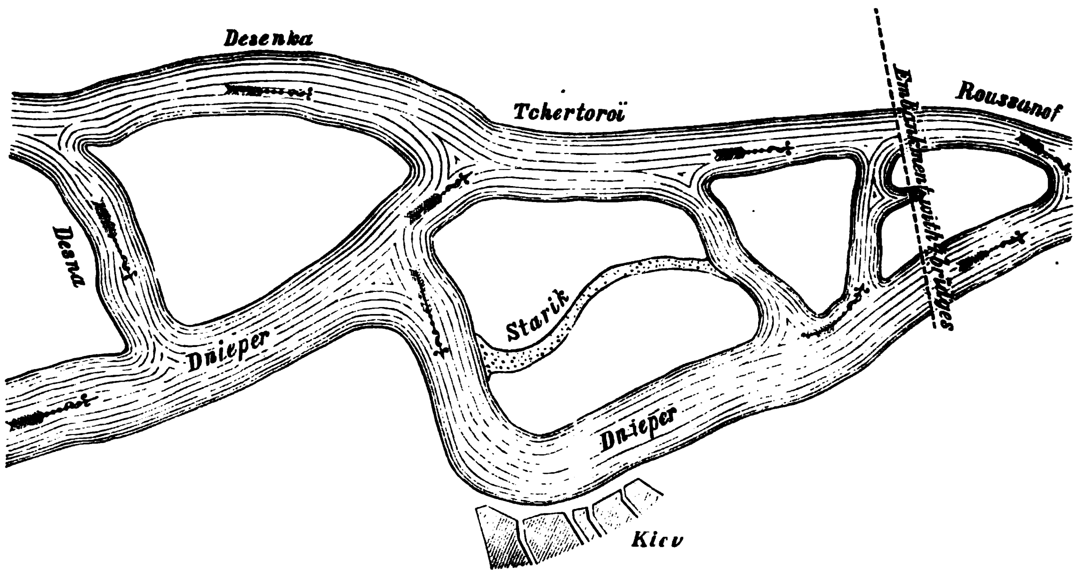


Fig. 2.

It appears from this plan that the Dnieper in approaching Kiev follows a sharp curve, the concave side of which is towards the town, and which does not coincide with the shortest road, which is taken by the water in spring when it can go straight across the fore-shore of the submerged left bank. This circumstance combined with the want of consistancy and the extreme instability of the sandy bed and banks of the river has facilitated the formation of lateral branches and has contributed to

render the current of the river in this place both variable and inconstant. Ancient plans and traditions that have come down to us show that the principal course of the Dnieper at a remote period divided into two branches, that on the left named Tchertoroi and that at the right named Starik, while on the bank where the town Kiev is built there was a series of sand banks and shoals which reached as far as the hills of Kiev where the Potchaina fell into the Dnieper, that little historical river in which under Saint Vladimir the Russian people was baptised.

In proportion as the town developed the inconveniences resulting from its distance from the navigable branches of the river made themselves felt and at various times the inhabitants found themselves obliged to take measures to draw the principal current of the stream within the neighbourhood of the town. For this purpose, according to the tradition, vessels laden with stones were sunk at the entrance to the Tchertorai, which reduced the bed of this branch and made a considerable portion of its waters flow into the right branch and towards the town. But it also happened that in the spring the high water overflowed on the side of town the banks upon which some houses had been built here and there without protection; then the inhabitants thought of turning the principal current into the Tchertorai branch and some canals were even dug with this object.

These works were only recommenced in our century. Between 1840 and 1850, Kiev having become by the wish of the Emperor Nicolas I an important centre, from a military, administrative and commercial point of view, of the vast and rich region of the south west of Russia, the imperial treasury assigned several millions of roubles for the construction of certain immense buildings for various military and civil administrations: at the same time it was decided to build a fixed bridge, on the system of bridges suspended by chains, across the Dnieper. It is also at this time that the state commenced the first works intended for the improvement of the Dnieper at Kiev.

In order to carry away the alluvial soil which had been deposited in the principal bed and to direct the course of the current it was resolved in 1842 to dam the Tchertorai in the place where it separates from the Dnieper and to direct its waters into the principal branch (1). At the same time a plan was formed to protect the bank on the side of the town and to build a quay to enable vessels to land their cargoes with ease. These works were completed between 1850 and 1860. Nevertheless the Tchertorai was not at that time completely dammed up by the dike of fascines at its entrance. For fear of sending all the water together, at its mean height, towards that bank that was not yet protected, an opening of about 50 m. was made in the dike. But the complete closing of the

(1) V. Plate I.

Tchertorai was especially advocated by the English engineers, Vignolle at their head, who were then by virtue of a contract with the Russian Government building in stone the piers of the suspension bridge below the quay of the town.

Whether it was with the idea of facilitating the construction of the piers, which was effected within a coffer-dam emptied by means of a pump, or in consequence of an insufficient knowledge of the *régime* of the river or a lack of exact data for calculating the spans of the bridge, in building it the English engineers committed two great mistakes, the consequence of which has been an organic irregularity in the distribution of the spring waters at Kiev, a circumstance which we are obliged now to rectify with great difficulty. The first mistake was in prolonging the suspension bridge by an insubmersible paved dike, by making three openings in this dike (in all four with that of the suspension bridge) and covering these openings with wooden bridges with struts on piles (2). These wooden bridges on piles being in the direct course of the spring high waters frequently when ice descended the river became damaged and it was necessary continually to rebuild them. The opening of the suspension bridge was about 680 m., while the total width of the three openings amounted to 900 m. This insubmersible paved dike was about 3 km. long, while the width of the valley inundated in front of Kiev and above the dam in spring was as much as 8 or 12 km. and the high water then rose 2 or 3 m. above the banks and all the islands.

The English engineers committed a second mistake by laying the concrete foundations of the piers of the suspension bridge at different depths and by allowing themselves to be guided by the form of the bottom as it existed at the time. The result of this has been that while the foundations of the three piles on the right were placed 10.80 m. below the level of the summer waters, the two piers on the left were built on piles driven into the bottom and cut off at the level of the summer waters. The character of the hollows under the arches of the bridge soon began to change and changed in an inverse sense. In the right hand arches the bottom commenced to rise, while it continued to get deeper in the left hand arches. This circumstance aroused fears as to the safety of the piers and required serious measures for the strengthening of the bottom around the piling which protected the concrete foundations of the piers. Finally in the spring of 1877, during an extraordinary rise of the river, the second in importance during our century, the wooden bridges of the dam were once more carried away, and in the opening left by the largest of them named the Roussanovsky bridge, 470 m. long, a new bed was formed, into which the current of the stream precipitated itself, leaving the fixed suspension bridge.

(2) V. Plate II.

The increase in speed of the high water in the two branches, the Tchertorai and the Roussanovska, endangered the existence of the single dam across the Tchertorai. This dam, although it was then completely closed, continually sustained injuries, either from ice or from the violence of the floods; finally during the winter of 1882 it became undermined on the righthand side of its base, and the current of the Dnieper again precipitated itself with extreme violence into the Tchertorai and the Roussanovka, abandoning the quay of Kiev and the fixed bridge.

All these changes in the Dnieper in consequence of the construction of the suspension bridge showed the necessity of regulating the course of the stream at Kiev, of closing the superfluous openings in the paved dike and bringing back the principal current to the quay of the town and under the fixed bridge.

In 1883 a project was formed for the regulation of a section of the river commencing above and finishing below Kiev. This section which measures about 20 km. in length begins with the confluence of the Desna, which falls into the Dnieper 10 km. above Kiev, and is limited down stream by the railway bridge of the line between Koursk and Kiev.

Thus the problem of regulating the stream at Kiev had not for its object, as is ordinarily the case, the creation of a navigable channel by means of dams and dikes, but an end far more difficult to attain, viz. to unite the ordinary waters of all the lateral branches into one and the same bed, direct, regulate and fix this current along the quay that already existed, reconciling all the above conditions with the necessity of making this current pass under the suspension bridge, as this was the most advantageous direction for it to take.

The system adopted was a mixed system, consisting of leading dikes, works along the banks and submerged cross dams. The top of the works constructed in the bed of the river rises to the line where vegetation ceases, which is 1.40 m. above the summer waters; they are built of sunken fascines, laid in some places after the Dutch method in the form of a fan and in others according to the manner employed by the Germans and Poles on the Vistula.

The following has been the order adopted for the execution of these works which have been carried out according to their relative importance and the sums' set apart each year for the purpose. First a leading concave dike was built in front of the old dam across the Tchertorai in order to dam up durably the principal lateral branch of the Tchertorai; dams were next built in the lateral branches in order to raise the bottom and unite their waters in one single bed under the suspension bridge. In the Desenk, which branches off from the Desna and falls into the Tchertorai, a dam of fascines in the form of a dike was raised at its point of origin with an opening to let out a portion of the water and matter brought down by the current so that this branch might be blocked up as soon as possible.

Besides the works laid down in the bed of the river a series of dikes has been formed along the banks to stop up the deep hollows and secondary canals which cut through a large number of islands between the principal branches of the Dnieper.

The results of the regulating works at Kiev have exhibited the following phenomena:

1. The three openings of the bridge formed by the paved dike have been filled up, and I would add that of the 900 m. which formed their total length, 700 m. are now closed by embankments, so that there is left for the river besides the passage of the suspension bridge only a narrow side-opening of 200 m. at the left hand extremity of the dike.

2. All the ordinary waters of the Dnieper are collected into one bed and are directed towards the quay of Kiev; at the same time the bed has assumed a more regular character, although it is not yet sufficiently constant.

3. A sufficient depth has been obtained and a free access for vessels to the quay of the town.

4. We have succeeded in giving to the current which passes under the Nicholas suspension bridge a course both regular and advantageous as far as regards the strength of the piles.

Having thus given some account of the works on the Dnieper in front of Kiev, we will now describe the phenomena of the scouring of the bottom and the banks which has taken place in the principal bed of the river, where as I said above, all the ordinary waters of the dammed up lateral branches have been gathered together. In the form of the banks of the regulated bed we have been guided by the general law of alternate concavities and convexities. The normal width of the bed at Kiev, calculated according to the formula of Ganguillé and Coutter, was found to be 350 m.; but this figure is as a matter of fact too large, for in the portions of the river contiguous to the regulated part, in which the bed has in certain places natural and very regular concavities and at the same time sufficient constancy, the width of the stream does not exceed 300 m. The curves which in these places limit the bed of the river are very different in form as well as in radius. These differences are such that it is impossible to deduce from them any general conclusions with regard to the law of their formation. Among the engineers who have during the last few years studied the problem of the influence of the form of rivers on the depth of their beds, we owe the most valuable conclusions to the celebrated French engineer M. Fargue, who has among Russian engineers an authority equal to his reputation. The results that he has obtained on the Garonne, where he has applied the rules and conclusions which the scientific study of the question has led him to form, have fully confirmed the correctness of his views and furnish us with one of the best and most fortunate examples of the

regulating of a river with an unstable bottom. The principal rules laid down by M. Fargue with respect to water-courses with unstable bottoms, deduced from his observations on the Garonne, are applicable in a general way to all rivers of the same class. Thus on the Dnieper also the regions of deep and shallow water in most cases are found below the apex of the curve and the point were the direction changes, and the curvature of the apex always determines the depth of the hollow. To reduce the net cost of the work while regulating as well as might be the course of the waters gathered into one single bed along the town of Kiev, the concave curves were traced as nearly as possible after the natural form of the banks, only the most marked irregularities of which were rectified. A form of bed was thus obtained more or less softened by concave banks in suitably chosen arcs of a circle, avoiding sudden changes in the radius of the curve in the junction of two consecutive arcs of a circle. The length of the curved lines, counted from the apex of the concavity of one of the banks to the beginning of the concavity of the opposite bank, varies between 3000 and 3500 m. The project had first been formed in 1882 to give to the opposite convex bank a direction parallel to that of the concave bank, but soon after commencing work it was perceived that in the place where the curve turned the channel lacked stability. At this point the current, not being affected by the steady flow observable in the concavities, spreads out and becomes dispersed and in order to secure a channel of the requisite depth in these portions, it appeared necessary to contract the bed by bringing

Fig. 3.

the banks nearer together. Thus 350 m., determined by calculation to be the normal width to be given to the regulated bed, on the hypothesis of a mean speed at the bottom sufficient to prevent the formation of sand deposits — a speed which under the local conditions ought to be about 0.35 m. — was found to be too high a figure for the places where the change in direction is met with. The formation of a channel having a serviceable section with a constant depth could not be obtained in these places, in spite of the contraction of the natural bed by building dikes in front of one of the banks. We have a striking example of this in the place where the channel passes by the quay of the town. Before the regulating of the bed the form of the hollows in this region, at the summer level of the water, was as shown in fig. 3.

After building groins of fascines in front of the left bank and decreasing the width of the bed to 350 m., the dimensions indicated by the theory, an arrangement of depths, as indicated in fig. 4, was after a while obtained.

Fig. 4

Moreover the stream divided in a manner which formed in the middle of the bed a slight shoal which the currents go round to unite again along the quay of the town, where sufficient depth for navigation is obtained. To lessen the change of direction in the channel at the point in question where the bed turns in above the quay of the town, it is now proposed to bring the two banks within 240 m. of each other.

The usual phenomenon of the formation of hollows along concave banks, which is explained by the crossing and accelerated movement of the currents, depends especially, according to the observations made upon the Dnieper, on the discharge of the river; this is never constant and in the spring, as has been said above, increases in the proportion of 1 to 40 or more — the ratio between the discharge of the river and the amount of water in summer. We have also remarked that the greatest depths corresponding to the concave banks are *almost always found, not at the apex of the concave curves* (which in our river are formed by arcs of a circle), *but at a distance of* $^1/_5$ *or* $^1/_3$ *below this apex*, and depend both on the length and radius of the curve.

With regard to the seventh question brought before the Congress, viz. the regulating of rivers at low water, there can be no doubt as to its possibility and it is actually managed on the majority of our rivers in Russia, provided in the first place that the season of low waters presents the greatest difficulty to navigation and that this situation continues throughout the greater portion of the time that navigation lasts. The principal obstacle is caused by the fact that on the greater number of our rivers it is impossible to regulate the spring currents. Russian rivers for the most part flow through plains and being fed in the spring by the waters produced by the melting of the snow which covers vast areas, they have formed very wide and flat valleys of inundation which often reach a width of 10 or 12 km. The bottom of these valleys is generally composed of pure alluvial sand, which is very unstable and reaches according to

Fig. 5.

soundings to a depth of 30 m. and more. After the spring waters have passed the course of the river commences to be unsettled, forming a large number of curves and bends, in which the water moves in a direction which not only does not coincide with that of the spring waters, but which is frequently at right angles to it. Examples similar to that represented in fig. 5 are not rare.

Under these conditions the dikes raised to regulate the bed of the ordinary waters may at the high water season produce directly contrary effect by facilitating the deposit of matter brought down in great quantities by the swollen waters. Thus, according to the measurements made by us on the Dnieper, the quantity of solid matter brought down in the space of 24 hours by the spring floods amounts to 150,000 cub.m.

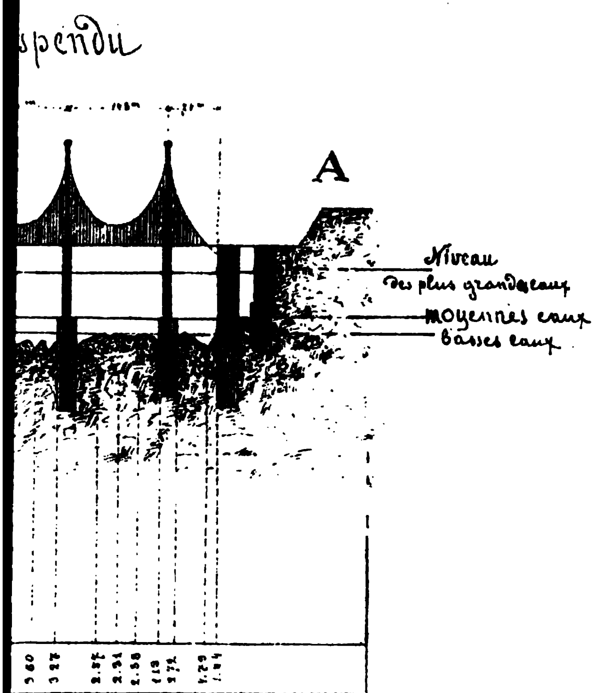
This circumstance added to the greatness of our rivers and the enormous destructive power of the ice when it breaks up, which occurs twice a year and little by little destroys our works, singularly complicated the problem of regulating the river ways of Russia. But the greatest of the evils to which Russian rivers are subject is the formation of masses of ice in their beds. In certain circumstances, the concurrence of which it is impossible to foresee, enormous masses of floating ice often having a thickness of about 0.80 m. and an area of 1000 to 10000 sq.m. pile one on another, obstructing the stream and thereby obliging the current arrested by this bar of ice to open for itself a new bed by ploughing up the bottom and the banks in the most irregular manner. Such unfavourable conditions do not deter Russian engineers from attempting to improve the *régime* of their rivers, principally in those regions where navigation meets with the greatest difficulties from the raising of the bed of the channel. Succesful examples of this partial regulation of difficult passages in our rivers have of late years become more plentiful. It goes without saying that in modifying thus the incline of a certain portion of the section regulated, great care is taken not to injure the *régime* of the neighbouring sections. This kind of work being still in our country of recent date it follows that we have at present hardly any observations capable of enriching science, but we are not without hope of collecting materials of value, which may be capable of solving various questions relating to the improvement of the *régime* of water-courses, and perhaps at some future Congress our colleagues will find some interest in the observations which we shall have to lay before them.

(Translated by FRANCIS A. OLIVER.)

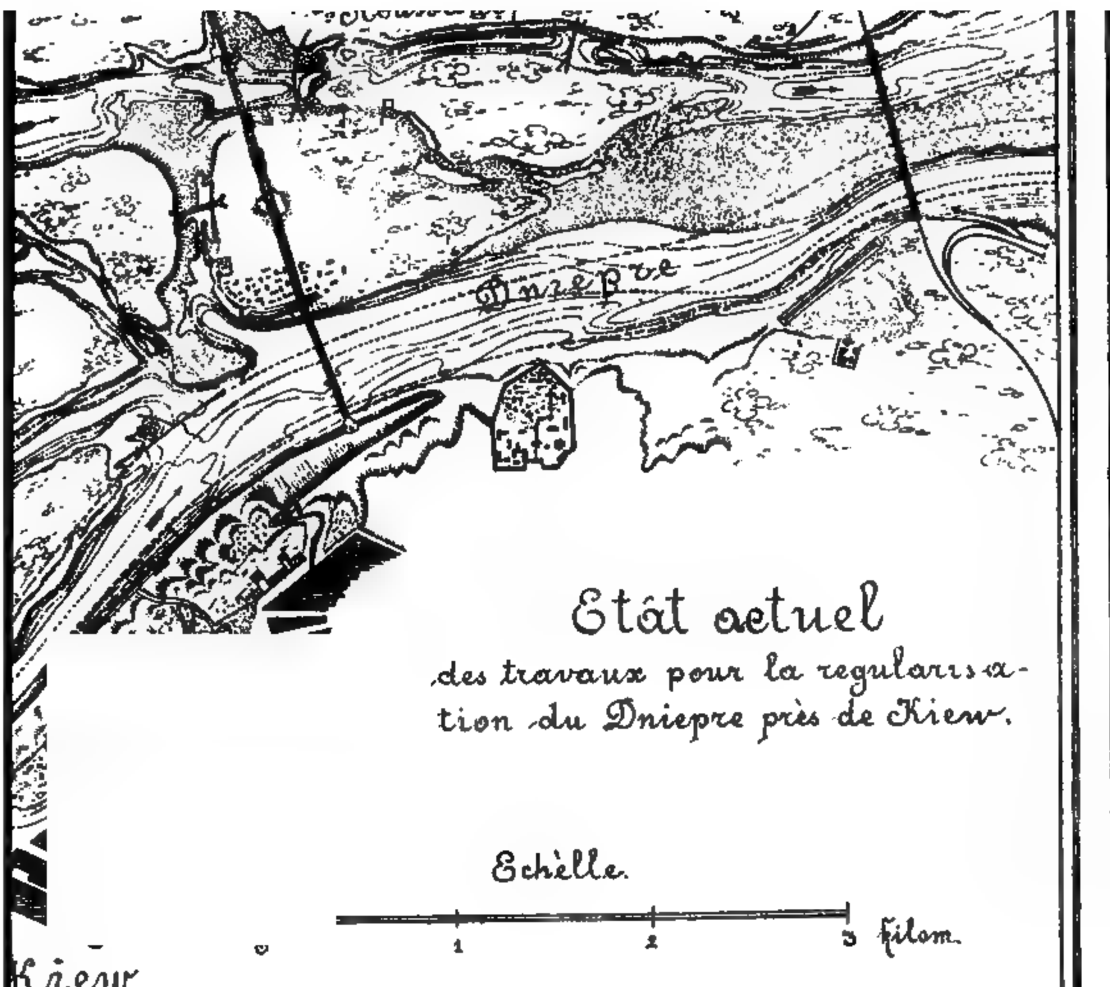
Inscriptions des Planches.	Inschriften der Zeichnungen.	Description of Plates.
L'approfondissement des eaux basses en mètres.	Austiefung des Niedrigwasserbettes in Metern.	Deepening of the bed in shallow places, in metres.
Basses eaux.	Niedrigwasser.	Shallow water.
Echelle.	Maasstab.	Scale.
Etat actuel des travaux pour la régularisation du Dniépre près de Kiew.	Gegenwärtiger Stand der Regulirungsarbeiten im Dnjepr bei Kiew.	Present state of the works for the regulation of the Dnieper near Kiew.
Moyennes eaux.	Mittelwasser.	Mean water-level.
Niveau des plus grandes eaux.	Höchster Wasserstand.	Highest water-level.
Plan du Dniépre près de Kiew.	Karte des Dnjepr bei Kiew.	Projection of the Dnieper near Kiew.
Pont.	Brücke.	Bridge.
Pont suspendu.	Hängebrücke.	Suspension bridge.
Profil sur l'axe du remblai.	Längsschnitt in der Achse des Erddammes.	Section through the centre of the embankment.

Ph

Planche N°. II.



spendu
A
Niveau
des plus grandes eaux
moyennes eaux
basses eaux



État actuel des travaux pour la regularisation du Dniepre près de Kiew.

VI[th] INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

7[th] QUESTION.

THE REGULATION

OF

RIVERS AT LOW WATER,

BY

HERR SEIDEL,
Inspector of Hydraulic Works. Memel.

THE HAGUE,
Printed by Belinfante B[ros], late A. D. Schinkel,
PAVELJOENSGRACHT, 19.
1894.

VI[th] International Inland Navigation Congress.

THE HAGUE, 1894.

THE REGULATION OF RIVERS AT LOW WATER

BY

Herr SEIDEL,

Inspector of Hydraulic Works, Memel.

During the last ten years the conditions favourable to navigation on the great rivers of north Germany have been sensibly improved in proportion as the methodical regulation of them has been effected. These improvements have been carried out for the benefit of the districts through which they flow and of the navigation on their waters by fixing the banks according to the corrected form of the watercourses and by regulating their width.

The width normalised by groins and in certain places by protected banks or parallel dams has been fixed in default of a scientific basis from such hydrological observations as it has been possible to make. The works have been carried to about mean waterlevel.

The contraction of the channel, has provoked the deepening of river-beds and scouring of the bottom. For this scouring action, while increasing the depth need not completely but only in some measure replace the surface that has been reduced in order to give the same volume of discharge because the latter increases with the increase in depth. The raising of the surface and swelling produced at first, a result which it would appear desirable to suppress and which requires a greater velocity and more energetic scouring action, will cease for the most part in course of time after the inclines have become equalised and a new state of equilibrium has been established, especially as by reason of the scouring the depth will every where become greater.

The method of regulating according to a fixed plan adopted up to the present has not always been sufficient and the results have not always been complete; it remains for technical knowledge to improve the situation with respect to commerce, wherever the need may be felt, by regulating the navigable ways and transforming the bed of the river in such a manner that the channel may offer throughout its length a sufficient width and regular depth, which even at a low water-level or at the lowest water-level may allow

boats of ordinary size to navigate when fully laden. This end can only be attained by regulating the transverse section in proportion to the quantity of water available, to the velocity of the current (that is in proportion to the incline, which changes little) and to the depth. Other reductions of the width of the summer bed need not be effected except when the usual correction is inadequate and the dimensions chosen are found to be too large. The actual decrease in the transverse section from the mean to the low water-level by means of the talus in use does not correspond to that of the volume of water necessary to give a sufficient depth. As an example we may mention the conditions of the Elbe between Tangermünde and the month of the Havel where the normal width is not so great as below the Havel.

The figures for the dimensions established have been borrowed from the „Report on the rivers Memel. Weichsel, Oder, Elbe and Rhine, drawn up by order of the Minister of Public Works, Berlin 1888", and refer to the mean and low water-levels.

No.	Water-level.	Height above the datum line at Sandau.	Discharge.	Width	Area of Section.	(v)Mean Velocity	(t) Mean Depth.
1	Mean.	2,26 m.	405 cu.m.	188 m.	517,5 sq.m.	0,90 m.	2,75 m.
2	Low.	0,59 m.	107 cu.m	178 m.	212 sq.m.	0,50 m.	1,19 m.

According to the formula for the velocity

$$v = c\sqrt{RI}$$

or

$$v = c\sqrt{IT}$$

the difference between the velocity at mean water-level and the velocity at low water-level when all other conditions remain the same, is in the following proportion:

$$v_1 : v_2 = \sqrt{t_1} : \sqrt{t_2}.$$

For v_2 0,59 m. may be substituted.

If a formula deduced from the hydrometric observations taken on the Elbe in 1885 be taken viz.

$$v = 46{,}91\ \sqrt{t} - \sqrt{I}$$

it will be found that

$$v_2 = 0{,}68 \text{ m.}$$

The actual decrease of v_2 to 0.50 m. is too great; the condition of the river at mean water-level and at lower level does not sufficiently affect the formation of a regular transverse section. A satisfactory formation of the transverse section will be more readily effected by means of the dams proposed in the first place for the consolidation of the ends of the groins. At present the latter do not regulate the form of the bed suitably to the discharge,

because they are too deep below low water-level and fall away too abruptly and are not long enough.

By making a more radical change in the form of the river, the discharge, and at the same time the force of the current, may be gathered into a narrow channel which should regularly decrease in width from the mean water-level downwards.

The question then rises upon what system is the new form to be given to the river to be based, whether sunken groins should be constructed to establish the new conditions, or whether training walls should be built along each bank or along only one bank with groins at given distances, as proposed by M. Franzius, Director of Hydraulic Works at Bremen (v. *Centralblatt der Bauverwaltung* for 1893, N^{0}. 1).

Before comparing the two methods with regard to their probable effect on the flow and bed of the river, it is necessary to make some remarks upon the construction and use of sunken groins and of leading dams.

For the entire transformation of the river-bed one is naturally inclined to choose the well tried system of groins, copying as far as possible a form of bed which resembles the profile it is desired to give to the river in question. Sunken groins must therefore, in places where stone is used for their construction and the cost is moderate, be built of stone with an incline which experience will indicate. When they are made of wood, that is to say at low levels, fascines will be used which will be sunk by placing stones upon them.

Sunken groins of wood will have a width on the top of the ordinary length of a fascine, that is 5 or 6 m. and the incline will be as gradual as possible, especially down stream, so as to resist the action of the water. In the same way the ends are widened and consolidated with a level talus and with bottom ridges. When stone is used the leading dams should be made of broken stones; the incline and dimensions given to these dams will be indicated by experience, while for the fascine work there must be stone work to sink it of the height and width which experience has recognised to be correct, where the river-bed is about the same height as the bed of the low water-level should be after the work has been finished; this will be the case in the transition from one curve to another. To counter-act the effect of the current leading dams must be constructed with fascine work with weights to keep it down at their base or upper part if rubble walls alone cannot be erected; Eddies should be suppressed.

Cross-works at present connected with inclined groins at various distances from one to another and joined to about every 3rd or 4th one may, when the attack of the water is less, be also formed of stone; when the action of the water is more violent they must be made of pile-framing and fascine work and a level talus must always be on the down stream side. They have like sunken groins a covering of fascines which can be easily repaired when damaged. A width of 5 or 6 m. at the top may be considered sufficient, while the top of training walls is 2 or 3 m. wide and a simple talus on each side is enough.

Supposing the river-bed at low water should have a depth of 1.5 m., the training walls should have a height of 1 m., at the most of 1.5 m., the foundations which sink into the ground being taken into account, for the top of them is taken at about 0.50 m. below low water-level and the bed slopes towards the centre. The cross works end at the height of the leading dams and gradually mount to the level of the inclined groins; they entail a continual increase in the transverse section. The mud collected by the dredging of the channel should be deposited between the leading dams and the fore-shore behind the cross works in order to increase their power of resistance. For in the case of the river-bed being too rough it is always necessary to have recourse to dredging to assist the function of the works and to counteract the too energetic action of the water.

The ideal cross section would be, after the intervals have been filled up, a continuous progression corresponding to the discharge from the low water-level up to the mean level, which in the curves would be found only on the convex side.

The position of the training walls on both shores in straight parts is easily fixed. The direction of the current regulates them in the transition from one curve to another; they will be parallel to the direction of the current, and not to the direction of the original course.

The passages which are not arranged according to the general formation of the bed of the channel disappear. In the curves a greater breadth must be given than in the straight portions, for in curves the velocity of the current is less and it is necessary to resist the force of the current, which is tending to undermine the concave bank and injure the works. Naturally the leading dams are not placed here at a great depth; the action of the water against the groins should be avoided by gradually rising ridges and by raising the bed of the river.

In order to increase the action of the groins the sand lying in front of the concave banks is dredged. As regards the concave banks the adjusting of them to the mean water-level is generally to be recommended, after the ridges have been constructed, for the sake of navigation. In this case the corrected shore lines for the mean and low water-levels coincide.

The system to be adopted for the regulation at mean water-level should correspond to the actual conditions. In river-beds that have been made too wide for the low water-level, the material of the bottom and especially the sand which is put in movement by the high waters are deposited as the water goes down when the velocity of the current is no longer sufficient to keep it moving. During high floods by their displacement they increase the transverse sections.

These conditions are met with on the Elbe below the Havel, while on the contrary the Memel is very much reduced at low water. Falling water must always make a deeper channel on account of its bed being higher and wider. This happens especially when the level of the water falls gradually and the

river bed is full, whereas a less depth is formed by a more rapid fall. Either the channel or the course of the river remain always in the same position between the banks in those places where the cross-section is not too large and where the construction of the bed is solid, as on the Elbe above Havel; or the sand-banks are moving irregularly in a down stream direction and are even thrown upon the least curved concave banks, as is the case on the Elbe below the Havel. In both cases the low water channel oscillates between the banks from one side to the other and the shallows in the navigable channel are found between two successive sand-banks. These regions determine the available depth and render useless places where the depth is greater. When the water subsides and is at its lowest, the number of passages of this class is generally getting larger, the channel becomes longer, the course of the river more sinuous, the fall less and the effective force of the current more feeble. The quantity of water spreads over the layers of sand that have bcen deposited and which do not dry and cross currents are formed; part of the water falls over the sand in a sidelong course and does harm its scouring action in consequence of the loss of force that it entails.

The capricious changes in the channel when the water rises and falls and the deposits of various forms should be avoided, care being taken to prevent the formation of cross currents and to consolidate the bed. The construction of groins at a low level would no doubt cause to appear a number of difficulties which while only works at a mean level are used and the beds are less confined, do not present themselves and cause no harm; but a closer examination of them would decide against the exclusive use of them. The partial abandonment of isolated works at a low level and the adoption of leading walls, or according to this system the connecting of the ends of the sunken groins placed farther apart by means of leading walls, entails a method of construction different to that at present in use. Before preferring one method to another it is essential to compare the probable influences of the two systems and to consider the different advantages and defects that they possess.

Leading dams at a low level on each side only settle the question of the regulation of the discharge at low water; a succession of side-walls is less violent in its influence than isolated works; there is less loss of force at the side of the stream, and therefore the average velocity is greater, the scouring action and the effective force more energetic. Also when the level rises the leading dams determine, as for as regards the greater volume of the water, the direction and utilise the effective force of the current for the scouring of the channel.

This *continuity* in the course certainly ought to influence advantageously the formation of more regular transverse sections and more equal depths as well as the maintenance of them. Groins form in the regular direction of the stream only isolated fixed points at certain distances apart and leave the stream to do the rest.

With the groins at present in use perfect results are not obtained, as the

current has not yet a fixed bed, because the groins on both sides do not act exactly as models even when (and it is not always the case) they are placed perpendicularly to the dlrection of the current and opposite one another; in fact the course of the river changes with the height of the water and in this case the normal profile is perpendicular to the line of the current and oblique to the course of the river. This is why groins are incomplete and constitute local works for impeding the water; for a regular profile they are out of place. Even in the case of more numerous isolated dams with sunken groins this defect in the construction of the groins cannot be entirely remedied.

With continuous leading dams an *equal incline* will be formed of the flow at low water when a proper height is chosen. Thus the incline when the water is at its highest level, which is more uniform, will be transmitted to the lowest level. In the same way a comparatively regular velocity will be met with afterwards in the channel and this will guarantee the preservation of the depth of the river-bed.

With the system of groins, in each place where the bed is contracted the fall is stopped which prevents the formation of a uniform velocity. A regular incline and uniform velocity are the first conditions for the preservation of a river-bed that is still unfixed. Works for the regulation of the movement of solid matter and the formation of sand deposits behind the works must also be considered as of great importance, as they determine the formation of these deposits and help to maintain a more regular profile. Only when in consequence of sand deposits in the river-bed the banks and shores are formed naturally at a low level according to the form indicated by the works, the stability of the profile it is sought to obtain is assured. By means of leading dams and shore connections the deposits in the actual bed of the mean waters will be thrown upon the intermediate spaces. After the regulation has been effected the main channel will contain but little solid matter.

By using groins the deposit of the sand will not be so certain. Below the groins the current which is confined by them expands; forming eddies it penetrates into the lower part of the succeeding interval and at a distance of 10 to 20 m. behind the works, according to the position of the current, the spaces between the works will not be filled by deposits.

A part of the deposit created by the fall is raised from the intermediate space on the concave banks at the first floods if the water has any force; the material of the bottom forms no deposits when there are no intermediate works to facilitate them. The water which surrounds and covers the sunken groins will act in the same way and probably most energetically; the consolidation of the bottom must therefore be effected to a more limited degree in the intervals between the sunken groins than in the case of leading dams.

The *preservation of river channels* which are found in their natural state or which have been dredged will probably be possible without further dredging, for the material of the bottom is thrown behind the leading dams. Nevertheless it must be supposed that it remains necessary to dredge systema-

cally along all the concave banks, because the regulation of the bed of the higher waters cannot be effected on account ot the expense it would entail and because the high waters would always carry away solid matter.

With the correction by means of sunken groins it will be necessary to dredge continually, because the masses of sand will then be carried away from the intervals when the works are submerged. As soon as the force of the current is insufficient to move the masses of sand they will be deposited in the bed of the river where they have arrived and also in that part of the channel where there are no groins and the width is increased.

The capricious formation of flat places is consequently more probable when groins are employed than when the leading dam system is adopted even if they are not to be looked for so much as has been the case hitherto.

If in the portions of the river that are to be regulated at low water large quantities of solid matter had to be expected, which came either from the upper stream or from side channels (such as may not have been regulated), these masses would have to be removed from the channel, for the sake of navigation, by means of more extensive works up stream in the shape of groins and intermediate works; it would be necessary to form a place for the deposits and for the matter dredged.

All regulation at low water and the formation of a deeper and narrower channel will help to effect the more expeditious clearing away of *ice*, for below it there is always running water and therefore, as soon as the thaw takes place, it will weaken. The ice will descend in a more regular manner, ice-banks and formations reaching to the bottom will occur less frequently, for the sand which favours the formation of these masses will be wanting and the floes of ice will meet with no difficulty in floating down the channel already or still open.

Low leading dams with shore connections, as well as raised ridges or sunken groins, offer no obstacle to navigation if the channel is wide and not excessively curved; the channel is confined, signs are put up to mark the route to be pursued by navigation.

The action of running water on leading dams is continual, but in consequence of the continuity of the works and of the regularity of the incline it may be distributed in a uniform manner and thus become less in each particular spot, the same is the case with connecting works and sloping groins. Leading dams and shore connections prevent the current from leaving the bed assigned to it, and consequently cross currents do not present themselves. It is essential before adopting low leading dams te experiment whether they are capable of withstanding the attack of the water. By placing them sufficiently low and leaving not too great intervals between the shore connections the ruption of the works is not to be feared, not is there any risk of causing eddies liable to damage the bed of the river. In the same way the placing of these works below low water-level is the most efficatious means of protection against the damage caused by overflowing and bij ice and the undermining of

the works, so that their durability appears assured without their base on the side of the current being strengthened with breast-work, except in the case of the concave bank where the attack of the current is most violent. With regard to observations upon the character of low leading dams we may refer to those made during the last few years upon the Weser below and above Bremen.

The conditions met with in these places cannot it is true be taken as an example for the upper course of rivers but nevertheless the advantages of leading dams with regard to the ebb and flood of the tide may be taken into consideration in treating the upper waters of these rivers, for the differences in the direction of the waters are not very essential and the conditions affecting the bottom are in theory the same. The way in which sunken groins are attacked is in both cases much the same.

These works dam up the water and increase the velocity of the current. This acceleration, causing in time of floods damage to the top of the works as well as the formation of cross currents and eddies below the confined portions, also partly tends to scour the bed and undermine the works.

The continuous and safe conduct which leading dams offer to the main current cannot be obtained by means of groins, except by increasing the number of them, especially where the current changes from one bank to the other.

All these works require the ends to be solid and capable of resistance and they are consequently more expensive. Long and practical experience alone can determine whether low leading dams or sunken groins are cheapest to construct and keep in condition.

The owners of property on the riversides are always afraid that, in seeking to improve the conditions favourable to navigation, some alteration may be caused in the character of the floods and high water and especially any effects be produced prejudicial to the cultivation of the lands.

There is as little ground for fear when the correction is effected by means of leading dams as when any other method is adopted and it is proposed not to alter, but to reorganise, the form of the bed. Moreover it is evident that the continual deepening of the bed of the low waters and the gradation of the course can only have a favourable influence on the flow, even when the water is at a high level, and also that the high waters are more easily carried when the transverse section is enlarged than when they are confined between banks of gravel. With regard to the high waters, however, the complete regulation of them is considered as pernicious.

It is very hard to eradicate this idea on account of the bad corrections made at an earlier date, and the people cannot be persuaded that the present works will not be equally detrimental; for reliable data for establishing a proof with mathematical exactness are wanting. But that this may be possible with future improvements it is to be hoped that it will be taken into consideration in advance and that all changes however partial may be recorded.

With this object the conditions of the flow at all water-levels should be

exactly noted as well as the variations in incline, the discharge and depth.

These details respecting the incline and level of the water should be recorded not only with respect to the gauges, but also wherever regulation works are undertaken. In this manner absolutely certain data will be obtained later with regard to the situation. The placing of the ends of the works lower or higher may cause a change in the level of the water; a considerable lowering of level will be obtained, if it is necessary, by lowering the level of the inclined groins and by placing the ends of them nearer the bank if the scouring and dredging have not been sufficient; while too abrupt a fall may be avoided by contracting the bed down stream, especially in the changes in directon.

These measures must naturally not be employed except when it is sought to obviate a rising or lowering of the bed in certain places.

Before deciding upon the form of cross section to be adopted, the factors of the discharge should be determined exactly; thus the principles respecting the details we mentioned above will be already fixed. The extent of the contraction for any point of the river will not be based upon the possible maximum depth, but the depth will be determined for the part down stream according to the depth which it is possible to obtain in the higher part.

The waterway open to large boats will end at this point, from here smaller craft will be used or (when the use of small boats is unprofitable from an economical point of view) the stream will be canalised.

The greatest depth will naturally end at the mouth of a tributary or at a trade or industrial centre. In the part frequented by large boats it is necessary to provide besides the depth necessary for navigation a sufficient width for lines of boats drawn by tugs to pass each other. The use of a steep talus and breastwork are to be recommended in these places in order that the full width of the bed may be utilised at low water.

The scientifically exact form of the bed has not yet been determined and it will be impossible to do so until the influence of the training walls upon the velocity of the current shall be as well known as that of the bottom (Cf. the report of Herr Jasmund, inspector of hydraulic works, *Zeitschrift für Bauwesen*, Berlin 1893).

According to the theory formulated in this report respecting the decrease in velocity at the bottom with the hypothesis that there is a similar decrease along the banks, it seems necessary to have recourse to the use of a steep talus which shall always be covered with running water, that is to say leading dams must be adopted.

The protection to the banks, such as is effected when leading dams are employed, is often built in a different manner for various levels.

On the mountain streams in Saxony and Bavaria blind work is used, fascines of Gumpenberg, which are simply leading dams.

On the middle course of the Rhine blind work is also used, as well as on the Elbe near Torgau and Anhalt and on the Saale.

also experiments may be made with regard to the force of resistance and the effect of low leading dams where they did answer the purpose of fixing the channel in the passages.

If the system of leading dams is appropriate it may facilitate the conditions favourable to navigation on rivers at low water.

The gathering together of the low waters into one channel of suitable form by means of leading dams laid at the height of low water should have an advantageous influence upon the direction of the water and offer the means to utilise more completely the discharge at low water and to take advantage of the possibility of creating a greater navigable depth.

Since in regulating a river-bed by means of low leading dams the pretentions of the dwellers on the river-banks must be respected, when it is a question of altering rivers, we may recommend the *employment of low leading dams before any other more fundamental system of regulating rivers at low water be adopted in order to obtain a greater depth and conditions more favourable to navigation.*

31

VI^th INTERNATIONAL INLAND NAVIGATION CONGRESS.

THE HAGUE, 1894.

7th QUESTION.

REGULATION OF RIVERS AT LOW WATER.

REPORT

BY

H. GIRARDON,

Ingénieur en Chef des Ponts et Chaussées
chargé du Service spécial du Rhône.

THE HAGUE,

Printed by Belinfante Bros, late A. D. Schinkel,

PAVELJOENSGRACHT, 19.

1894.

VIth International Inland Navigation Congress.

THE HAGUE, 1894.

REGULATION OF RIVERS AT LOW WATER.

BY

H. GIRARDON.

Ingénieur en Chef des Ponts et Chaussées chargé du service spécial du Rhône.

I.

GENERAL REMARKS UPON THE CONDITIONS OF THE FLOW OF WATER AND SOLID MATTER IN RIVERS OF UNSTABLE BOTTOM.

Most rivers of unstable bottom flow through valleys where the soil is composed of ancient alluvial deposits the thickness of which is generally considerable.

In their natural state they change the position of their principal bed upon the submersible plain, carrying it from one side to the other of the valley.

Every flood of importance brings down fresh solid matter from the tributaries, and also carries away something from the bed and banks of the principal water-course, thus modifying both its form and position. When the waters subside the submersible plain is found to be cut up by a number of branches, between which the discharge is divided, and these leave large spaces covered with gravel and sand between their respective beds. Such lands are generally unsuitable for any cultivation; after some years they become covered with shrubs and sometimes with trees; but their form is constantly variable and their existence is not permanent; the most recent floods may increase them, but they are more frequently washed away by them to be reformed elsewhere.

In great water-courses the space occupied by these variations may be very considerable, for they may reach the foot of the mountains on either side of the area occupied by the bed of the great floods and they frequently cover stretches of country several kilometres in width.

Sometimes on the contrary the bed is confined, the mountains which form the limit of the valley are close together and the water-course

passes through a narrow and deep defile. Such is the famous defile of Kazan on the Danube and such on a small scale are the gorges of Pierre-Châtel and St Auban on the Rhône.

At other times, without the shores being so near together, a mass of rocks traverses the valley near the surface of the water, often with points emerging, thus forming rapids like those of Struden or the Iron Ports on the Danube or the falls of Sault on the Rhône.

These passages between serried mountain chains or over bars of rock are not only indispensable as regards the formation of the bed, but they also occasion peculiarities in the course.

In deep and narrow defiles the incline, often considerable when the water is high, becomes less and sometimes almost imperceptible when the water is low, so that the course at low-water comes upon a level run, or nearly so, preceded and followed by more pronounced inclines.

Rapids produce similar effects. In time of low water it is ascertained that on a ledge an abrupt fall is preceded by a gentle incline and in some places by normal inclines.

However, this form of course is not invariable; although in these passages the water flows over hard ground which it is powerless to remove, its action nevertheless has some effect upon it; a part of the effective force is lost in friction against the rocks over which it flows and which it gradually wears away, and if no flood causes the course to change, if its action continues for a long succession of centuries, it finally digs deeply into and opens a passage through them. This is the origin, not certainly of all defiles, but at least of a certain number. But compared to the time which regulation works may last, the modifications which these passages undergo are insignificant. And as on the other hand the works it is possible to carry out cannot, without exceeding the limit of cost admissible, effect more than the improvement of local conditions or influence a wider area than that for which they were undertaken, these passages should be considered to determine fixed points both in the form of the bed and in the course, and thus establish a clear line of demarcation between the character or constitution of the various sections of the stream which they separate.

The conception therefore is here at fault which is often formulated for the course of a stream and according to which a series of gradually decreasing inclines should be formed; neither does it answer in the intervals between these passages as we shall see later on. In order that an obstacle may stop the scouring process effected by a water-course, form a bar and reduce the incline up stream to increase it down stream, it is not really necessary for this obstacle to present as great a resistance as the mass of rocks; it is sufficient that the undermining influence necessary to remove this obstacle be greater than the effective force of the water.

This circumstance is often met with and among others tends to give the course a less simple form than the parabola, and we only meet with it approximately realised in water-courses which have no tributaries or only tributaries of small importance, or in the parts of other rivers which receive no tributaries of any considerable size.

Between these accidents of mountains which only occur at wide intervals, plains of alluvial soil, which we have described and in which on the contrary everything is variable and continually unstable, sometimes extend over several hundred kilometres. The form and condition of the bed depends at every point and at every moment upon the nature of the soil and the incline, the discharge of water and its variations, circumstances which change under the influence of causes proper to the water-course itself, causes which are themselves modified by the tributaries which successively swell its current.

Each of these tributaries has its own characteristic constitution and consequently a different action, and the water-course which is affected by the resulting action of these tributaries is modified in various ways according as they act collectively or separately.

Some of these tributaries are themselves rivers of considerable size and furnish the principal water-course with an appreciable portion of its discharge; but whatever their importance may be the regularity with which they contribute to its alimentation is most variable.

Some proceed from mountains more or less lofty or situated in comparatively hot regions and their character then especially depends on the temperature which accelerates or retards the melting of the snow or ice. Their waters have a low level in winter and an average level in summer.

The tributaries whose basins are wooded or grassy and which flow through valleys with gentle inclines have a peaceful and regular character. Their discharge even in the dry season always preserves its relative importance, their floods gather slowly and last long, and the difference between their maximum and minimum discharge is moderate.

Those on the contrary whose basins are bare and inclines abrupt are diluvial in character. Their discharge when the water is low becomes almost *nil*, their floods rise suddenly and rapidly subside, the difference between their maximum and minimum discharge is very large; they suddenly pour forth enormous quantities of water which rapidly flows away, sometimes in a few hours, relapsing immediately afterwards to a very inconsiderable discharge.

Between these extremes are included all intermediate forms, and among those which partake of both characters there are some whose upper portions proceed from high mountains and flow over considerable inclines, while their lower course stretches over extensive plains. Their floods are here rapid as in torrents, but their discharge when the water is low nevertheless remains considerable.

If the different tributaries present very decided varieties as regards the character of their waters, they show differences quite as marked as regards the dimensions and the quantity of the solid matter that they carry down.

All rivers, with the exception of some springs which flow over hard ground at a gentle incline, have a double discharge—that of the water and that of the solid matter brought down. The flow of these is produced in very variable proportions in different rivers, or in one and the same river according to the circumstances and the state of the water, and it is regulated by laws with which we are very imperfectly acquainted or, to speak more correctly, laws which are unknown to us and which will probably remain so for a long time.

We know however that there is a relation between the quantity of water and of solid matter. The most simple observation shows us that the quantity or volume of solid matter brought down increases, all other things being equal, with the volume of solid matter in movement; it also shows us that it increases with the incline in the river-bed. If it depends on these two elements which influence the effective force of the river, it depends equally on the resistance opposed to this force, on the nature more or less unresisting of the ground over which the river flows, on the cultivation, woods and grass upon the slopes, and all those circumstances which combine to prevent the wearing away of the bed and any decrease in the effective force of the water.

Water-courses of a quiet character which flow over gentle inclines, the upper basin of which is wooded and grassy, generally bring down a large volume of water but little solid matter; during their floods however they carry with them a large quantity of the latter in the form of fine sand and light clay.

The water-courses, on the contrary, which partake of the character of torrents carry down large quantities of solid matter. In the upper part of their course they often roll down great lumps of earth the edges of which are hardly touched. These lumps stop at the foot of steep inclines, without however there acquiring a definite and constant position; but from this point their movement by successive stages becomes slower, until they are first carried down in the general movement of the descent of alluvial deposits or are removed by an upheaval of the bed and become broken up. The incline becomes more gradual the further from the source and the volume of solid matter decreases, either because the lighter portion only can have been carried so far, or because the rest has been worn away and broken up on the journey.

These phenomena are particularly noticeable in torrents properly so called, because the degree of the incline and the excessive variation in the discharge place it as it were on a larger scale and allow of better observations being taken. The general form of these water-courses may

be regarded as two cones, the upper of which has its top turned down stream, forming the vast funnel which constitutes the receiving basin and which wears away and changes its position in course of time, while the lower of them has its top turned up stream and is formed of all sorts of *débris* gathered from the first, *débris* which presents itself in every direction and spreads the further the more finely divided it may be and the less abrupt its natural angle of repose. These two cones are united by a passage more or less long and rapid, which constitutes the bed of the torrent. When a portion of the bank is worn away the *débris* which descends by this passage continues its fall over the incline formed by the preceding *débris*, over which the bed wanders guided by the resistance it encounters; the cone is worn away little by little while it grows longer and longer until it reaches the principal water-course which receives the torrent and into which the solid matter brought down so far falls together with the water.

Quiet rivers whose course appears quite different are none the less subject to similar phenomena, which occur with the same general though less pronounced characteristics. They all take solid matter from their beds, roll it along mingled with that brought down by their tributaries, wash it away in greater quantities in time of in flood, deposit a portion of it as the floods subside to take it up again later and conduct it by successive stages to places where the inclines are less steep; here these substances are exposed in a more or less flattened cone, they advance progressively and reach the more important water-course which in its turn takes them up until at last by a series of similar phases they arrive at the sea, into which the cone of evacuation of the river advances a certain distance and preserves its form according to the more or less energetic action of the tide, the currents and the waves.

In this inccessant levelling of the earth's surface which is effected by rivers, the water passes through a constant cycle and follows a continuous movement, descending from the mountain to the sea, where it evaporates, to return through the influence of winds from the sea to the mountain. But if on the whole the movement of the water has the character of continuity, its fall upon the earth's surface appears on the contrary to be intermittent, or more properly speaking periodical, and gives that character to the movement of solid matter which it is observed that it provokes. Every fall, that is to say every flood, detaches fresh particles from the mountain, stirs up in its passage the solid matter already collected in the bed, carries them along so long as the mass of water in movement has sufficient force, deposits them to take up others less heavy, when it can carry them no further, and finally conducts to the sea those of them which being lighter have already by preceding floods arrived nearer the river's mouth.

In this manner the descent of solid matter from the mountain to the

sea takes place somewhat after the fashion of the propagation of a great wave which the water-wave raises in its course and which subsides with the water; its magnitude and length vary from point to point by reason of the continually varying circumstances encountered in its course.

It is clear also that this rate will be the more marked as the periodical character of the movement of the water is more pronounced, as the difference between the maximum and minimum discharges is greater, the inclines more accentuated and bare, and the flow more rapid.

On the contrary where the watercourse depends only on the nature of the rains, where the nature of these rains is itself more regular, where the ground which receives them is more pervious and retains them longer and in larger quantities to part with them by degrees, where finally the inclines are slight and the flow regular and gentle, the wave will lengthen out and be depressed, but it will never be effaced and the movement of solid matter will always remain intermittent and always be caused by a series of successive violent movements separated by a series of stops and pauses.

This is a necessary consequence of the periodicity of the movement of the water and the invariability of the discharge. The force of the water only causes the movement of solid matter when the former reaches a certain volume, which may be called efficient, and when by the decrease of the discharge it becomes less than this volume the movement ceases and a deposit is formed. It is a natural law that it is impossible to infringe and the engineer in devising improvements for the regulation of the bed must abandon the idea of substituting a continuous movement for this intermittent movement and confine himself to foreseeing the position of successive haulting places and to regulating as far as possible the form of the deposits.

But this is not the only fact which observation enables us to verify. It is possible to deduce other facts quite as certain, other consequences quite as necessary to the reciprocal reactions of the movement of the water and the solid matter, by making a closer examination of the action of this effective force which varies continually over ground offering an equally variable resistance.

We have said above that the effective force increases with the amount of water in movement and with the incline. In an interesting memorandum published in the Annales des Ponts et Chaussées (1879, Vol. II), M. du Boys established that this power is directly proportional to the volume and the incline, so that the effective force exercised over a square metre of the bottom by a prism whose base is 1 sq. m. and altitude equal to the depth H of the water-course at this point, if i represents the incline, is found to be

$$F = 1000\ Hi.$$

This expression, established without reference to any theory of the

flow of water or any hypothesis respecting the variations of speed, supposes only that in the uniform movement the apparent active force of the volume of water is constant; we admit it for our explanations because the only hypothesis upon which it is based appears to us difficult to contest. We will however only have recourse to it because it simplifies the language; but we have no intention of putting through a process of calculation such complex phenomena as those which we are studying, nor of seeking to express in figures the effects produced. We only seek to determine the sense of it, so that our conclusions shall remain exact even when the law which connects the effective force of the river with the volume and the incline may differ from the idea of simple proportion, because it is certain that the variation of this force depends on that of the volume and the incline and is felt in the same direction.

If it is possible to conceive and even to express in a simple manner the force calculated to modify the bed of a water-course; it is not the case as regards the forces opposed to it.

These resisting forces are extremely variable and it is impossible to give a simple expression for them; but a certain number of the causes affecting the magnitude of them may be found. We shall confine ourselves to indicating the principal of these.

In the first rank must be placed the dimensions, density and weight of the solid matter. The influence of these causes is evident and the most superficial observation of them, or mere common sense, is sufficient to understand that the finest and lightest solid matter is most easily carried away.

It should be remarked however that the matter composing the bed of a water-course is not always the same, but on the contrary differs greatly in dimensions, nature, and form and is mixed in very variable and different proportions; the more or less intimate conditions of this mixing influences and modifies their individual resistance to the current. Mixtures of moveable gravel and pure sand are met with, as well as more resisting mixtures of gravel and argillaceous sand, masses of rocks and mud firmly stuck together and conglomerate lumps which present a resistance similar to banks of rock.

The shape of the pieces of solid matter has equally an influence upon the process. It is clear that round stones are more easily put in movement than sharp cornered or flat stones. Fragments of rocks descended from the mountain lose their angular form, they get blunted in successive violent movements and assume most various shapes, either because their faces are not equally exposed, or because their hardness is not the same on all sizes. The result is that all shapes and sizes are found from perfectly round pebbles to absolutely flat stones.

The manner in which these stones are grouped and mixed together has an evident influence upon their resistance to the current, but this resistance

also depends apon the way in which they lie. A flat stone laid upon its smaller side will be more easily carried away than if it lies upon its flat side, and it is evident that once set in movement, if it should stop or fall without anything opposing it, it will rest upon its flat surface. Therefore, if in a current which carries with it a quantity of pebbles, a large proportion of which are always more or less flat, the effective force should decrease, the pebbles will be deposited on their flat side one above the other; and when after a flood a recently formed bank of sand or shingle, which still preserves the form given it by the action of the water, be examined, it will be found that the stones are laid one above the other precisely like the scales of a fish. Sands so formed and composed of very unstable material will throughout present considerable resistance to the current according to the set of the stones. This resistance would be almost *nil* to a current coming in the other direction and but slight for a transverse current. It is thus that we can explain the existence, often long maintained, of banks which in themselves are unstable and are exposed to the full force of the current, and also their sudden disappearance under the influence of a flood less considerable than others they had resisted, but in which the direction of the current has been modified.

The effective force of the current is exercised over a bottom composed of equally heterogeneous and resisting elements. It can be conceived that when the current is feeble it will act only on matter offering a feeble resistance, since in proportion as it increases it will put in movement matter of a more and more resisting character. Therefore the finest and lightest description of matter will first be put in movement, then successively and by order of resistance larger and heavier substances. Inversely when the effective force shall decrease the solid matter will be deposited successively, the larger and heavier elements first, and so on down to the finest and lightest.

Observation entirely confirms this. If we look at the water in a river that has been low for a considerable length of time we generally find that it is clear. If the bed is composed of large fragments no movement of solid matter will take place, but if it contains fine and closely packed sand the clearness of the water is often compatible with a certain movement of the bottom and often enables us to perceive the grains of sand which are washed down. In proportion as the discharge increases, that is to say the depth and the volume, the movement of the bottom increases and becomes faster; shocks are produced, small whirlpools are formed and the solid matter is no longer simply rolled along, but is stirred up and mixed with the water. The latter becomes first discoloured, then troubled, then muddy, as when a vase containing clear water and a sediment is violently shaken. The discharge always increasing and with it the effective force of the current, solid matter of a larger

and larger size is put in motion, and if we go down the river in a boat without rowing or making any noise it is easy to hear a continually increasing sound mingled with loader and harsher noises, which exactly remind us of the noise made by pebbles rolling down a slope as they strike against one another and are frequently hurled a considerable distance by the shock. Exactly similar movements take place when pebbles are washed along in a water-course, and it is not unusual after a flood to see pebbles as large as one's fist, sometimes as big as one's head, deposited outside the bed three or four metres above the low-water mark and beyond the dikes above which they have been cast. This movement and noise is the more marked as the discharge increases; the size and quantity of the solid matter increase at the same time and during the highest floods of large water-courses a sound is produced like a continuous fall and precisely similar to the roaring of the sea.

Then when the water subsides the same phenomena are produced inversely, the larger fragments are deposited first, then the rest successively, the lighter substances only remaining mingled with the water, which ceases to be muddy, becomes discoloured only, and finally clear.

To each permanent state of the water therefore corresponds an effective force which should be counteracted by the wear and movement of the solid matter. Once the quantity of matter corresponding to this power is in movement, the current is incapable of carrying down more: it is then, as has been correctly stated, saturated. If the volume of water in movement or the incline change, the saturation capacity also changes and the current deposits or gathers more solid matter.

These continual variations in the effective force of the current or the saturation capacity of the water on the one hand and the resistance of the bed on the other must have the effect of constantly modifying the form of the bed, and this explains the variable condition of most water-courses in their natural state.

If these variations are considerable and frequent, the form of the bed will be unstable and continually changing; but every circumstance which has the effect of decreasing the changes caused by one or other of these forces, or of making them periodically acquire the same values, will restrict the modifications of the form of the bed or periodically occasion similar modifications. And as among the different phenomena which take place on a water-course we can distinguish certain things which reproduce themselves, such as forces which are always exercised in the same direction, or on the other hand there are places where the resistance remains the same either naturally or in consequence of improvements, it is not impossible to determine a number of constant conditions which the formation of a river should satisfy.

In the first place it is clear that if the floods only brought down an increased volume of water, their effect would be to wear away the bed,

to deepen it by degrees and progressively decrease its incline, until it should be reduced to a condition where all movement ceased. But such is not the case. They wash down, mingled with the water, a quantity of solid matter stirred up in the principal basin and the basins of its tributaries.

For the bed to maintain its general position without being worn away or raised, the volume of matter brought down by each flood must be equal to the amount ejected. It is evident *a priori* that this equality will not be produced in every flood, that some will carry down more, others less solid matter and that a certain mean stability will only result from the alternation of high and low waters.

But the successive tributaries which a river receives have not all the same nature or constitution. They will consequently each have a different influence upon the conditions of the flow of the principal water-course and upon its form.

When a tributary falls into a water-course it is in a state of saturation which corresponds to the volume of the water and the incline upon which it flows. The water with which it is about to mingle is itself in a state of saturation corresponding to its volume and incline. The waters and solid matters of the two water-courses intermingle. If the new volume of water and solid matter corresponds exactly to the state of saturation of the mixture as regards the the incline at which it flows, nothing will be changed in the movement of the solid matter, which will continue to descend as though no mingling had taken place.

But it may be conceived that such a condition is not realised in practice and that the quantity of matter resulting from the supply of the tributary together with that of the principal water-course will never be exactly equal to that which corresponds to the state of saturation of the new volume of water. It will be either greater or less.

In the first case a part will be deposited which will raise the bottom and increase the incline of the deposit down stream, until the effective force of the current shall have become sufficient to carry away all such supplies.

In the second case the water will become saturated at the expense of the principal bed, which will deepen while the incline down stream of the tributary will decrease, until the effective force of the current becomes equal to the power necessary to remove the solid matter.

But among the tributaries which a water-course receives, there are some whose nature is quieter than that of the principal water-course and others on the contrary more difluvial in character.

The first will carry down more water than solid matter. After their junction the water in the main water-course will be below the saturation point, the bed will be worn away and the confluence will be followed by more pronounced inclines than those which precede it.

The others on the contrary will carry down much solid matter and

little water. After their junction the united waters will be powerless to wash away the whole of the solid matter, a part of which will be deposited, the bed of the principal water-course will rise and the confluence will be followed by less pronounced inclines than those which precede it.

Each tributary therefore in consequence of the difference between its nature and that of the main water-course, will determine a break in the general incline of the water-course. This effect will be more or less marked according to the relative importance of the two water-courses; but if the principal tributary may be compared as regards its discharge to the main water-course, the effect will be considerable and the resulting modifications will influence the form of the course in a more pronounced manner than such resisting obstacles as ledges of rock; they will continue moreover until a distribution of the inclines is established, so that the effective force at any point will acquire the value which corresponds to the power expended in ordinary floods. The incline will then become constant so far as it is possible for it to be, that is to say that except in quite extraordinary floods, which stir up the bed to the very bottom, changes in the incline will be reduced to an oscillation within the narrow limits of its average position.

Observation fully confirms these remarks. The Rhône in particular offers several examples which make the fact sufficiently evident.

In the middle of its course it receives three tributaries which, without being as large as itself, are nevertheless considerable water-courses — the Ain, the Saône and the Isère.

The Ain is of a diluvial nature, its discharge at low water is very small, its discharge at high water considerable, it flows over friable ground and carries down large quantities of solid matter. It should therefore at the confluence occasion a considerable deposit and its cone of evacuation should create a bar across the valley, while determining down stream more pronounced inclines than up stream. In fact from the falls of Sault to the confluence with the Ain, that is over about 30 km. above this confluence, the average incline is 0.30 m. per kilometre, while below this confluence and as far as the confluence with the Saône, over 35 km., the average incline is 0.81 m. per kilometre.

The character of the Saône on the contrary is quiet; it only carries down sand and shingle; the volume of water is great, that of the solid matter small; its action therefore should be the inverse of the Ain and wear away the bed of the Rhône and reduce its incline. In fact while above the confluence this incline is as we have just seen 0.81 m. per kilometre, down stream on the contrary and as for as the confluence with the Isère, over a distance of 100 km., it is not more than 0.50 m. per kilometre.

Finally the Isère has, like the Ain, a more diluvial nature than the Rhône, it should therefore have the same effect as the Ain, occasion a rising in the bed and an aggravation of the inclines down stream. In

fact, while between the Saône and the Isère the average incline is 0.50 m. per kilometre, below the confluence it increases to 0.775 m. and maintains this angle for a distance of 90 km., until the Rhône, swollen by a series of less important tributaries, carries down a volume of water sufficient to reduce the incline to 0.50 m. per kilometre.

All the tributaries evidently do not act with the same force on the distribution of the inclines, but at a slightly different angle. They all have a similar action which is felt by the introduction of fresh and less marked, though more frequent, breaks in the form of the course, and these breaks are determined by ledges of rock and the large tributaries. And as, at least as far as concerns the time it is sufficient to regard for the duration of the regulation works, the general conditions of the nature of the main water-course and of the tributaries are very slightly variable, the influence of each tributary is always felt in the same direction and will always tend to give a certain permanency to the form of the course and the position of the deposits.

Still this influence is not alone to be considered; if it is predominant in the case of large tributaries it is less so when they are small; its effects must combine with those produced in the main bed and which result from the distribution of the resisting forces throughout its length. And it will immediately be understood that the form of the course and the position of the deposits will become the more constant as the situation of the resisting forces shall itself be more fixed.

It is therefore important to describe the influence which the distribution and nature of the resisting forces met with in the bed of the water-course exercises upon the general conditions of its form and inclines.

Let us first examine the form of the river. If we suppose a rectilinear bed, the transverse section of which is rectangular and in which the water flows with a depth and incline such that the effective force of the current is insufficient to put in motion the solid matter which constitututes the bottom and the banks, the flow will continue indefinitely without causing any change in the form of the bed or the course. This is what takes place for example in a canal of masonry.

But if the bottom is not absolutely resisting, when the discharge and the depth increase the effective force of the current will become superior to the resistance of the bottom and the movement of solid matter will commence. In order that the section should remain rectangular and the bed rectilinear, it would be necessary that at every point the quantity of solid matter carried off should have exactly the same thickness, which would require that the effective force and the resistance should everywhere be constant. It is evident that this conditon is never fulfilled in natural water-courses. On the contrary, the volume of water will find before it materials offering very different resistance and the current will open a passage and establish itself in the line where it meets with least

resistance. A *thalweg* will thus be formed, that is to say a line where the depth is greatest, and upon this line the effective force of the current will increase while it decreases over the rest of the bed. The scouring process will therefore become more and more energetic until a new form of course is obtained in which there will everywhere be equilibrium.

The current will therefore find itself turned aside from its primitive direction parallel to the banks and thrown against one of them. If this bank is unassailable the force will be spent in whirlpools which wear away the bed and the current will cross over to the opposite bank, it will pass from one to the other and pursue a more or less sinuous route, the form of which will be determined by the new initial direction of the water and the stability of the bottom. If the bank is not unassailable it will be washed away, the deviation of the current will be accentuated and this effect will continue until sufficient resistance is met with to cause a turn in the current. The same thing will take place therefore in either case, the change in direction or the curve followed by the new bank only being more accentuated in the second case than in the first.

It is evident moreover that one bend will be followed by another and then a third, so that whether between unassailable or between crumbling banks the current will follow a sinuous course and pass continually from one bank to another.

The sinuous forms which all rivers present is therefore not only general but also necessary and results from the heterogeneous constitution of the bed; but we can easily understand the influence exercised upon the constancy of the channel by the consolidation of the banks; it limits the extent to which they are washed away and more especially affects their form which, by determining the points where these bends occur and the direction of them, that is the initial direction of the current when it abandons one bank, leaves only the resistance of the bed as a variable element of its ulterior direction.

The transverse section gives rise to equally important observations. We have pointed out that the rectangular form of this section, that is to say the absolute flatness of the bottom, was not more constant than the rectilinear direction of the current, and we have observed that this section deepens first where the soil presents the least resistance; but after this first modification has been produced the depth and the incline cease to be constant and the effective force of the current varies from one point to another in the section. The position in the section of the deepest hollows, and consequently the position of the line of the *thalweg*, will therefore depend at once upon the resistance of the bed and all the circumstances calculated to influence the effective force of the current.

When the current strikes against one resisting bank from which it crosses over to the other, the waters successively arrested by the obstacle

they meet with create a pressure which must be counterbalanced by an opposite pressure and the level rises along the wall that is struck. The same thing occurs for the same reason when the current follows the concave bank; the centrifugal force drives the water against the bank and is counterbalanced by a pressure of the water nearest the bank, the level of which is raised. In both these forms the surface of the water is not horizontal in the transverse section; it indicates a rise against the bank, a deviation which it is easy to observe and is often pronounced enongh to be apparent to the eye.

The consequences of this as far as the shape of the course is concerned are sufficiently important for it to be useful to examine them in detail, and to simplify our explanations we will first take the case that most frequently occurs, namely that of a cencave curve (1).

We have said that as any given volume of water approaches the bank it exercises on that immediately in front of it a pressure which must be counterbalanced by a rising of the surface; but as the speed is not the same throughout a section of the current, being greater near the surface than the bottom, the pressure exercised by one section will not be equally distributed over the whole of the preceding section; the upper stratum animated by a greater speed will exercise a greater pressure, and the lower stratum a less pressure than the middle stratum. The upper stratum will therefore force back that which immediately precedes it and will create a cross current against the bank. This may be easily observed. Against the bank the strata successively swamped by the succeeding strata will gradually sink down and thus create a descending current; arrived at the bottom and meeting with strata that exercise less pressure they force back the latter and create a cross current, leave the concave bank and return to their point of departure creating an ascending current along the opposite bank. So that at the same time that they take part in the general movement of the translation of the mass of water, they follow a sort of circular movement in the transverse section, and finally their resulting movement being very different from the movement of parallel currents will be somewhat spiral in character.

This movement will necessarily influence that of the solid matter. If we first suppose the bottom to be horizontal the effective force of the current will be greater where the depth itself is greater, that is to say on the side where the deviation takes place; as the water must become saturated with solid matter it will carry away more from the concave than the convex side, and as the movement constantly carries it from the concave to the convex bank, where the effective force of the current is less, a part of the solid matter will be there deposited. This effect will gradually

(1) Boussinesq. Essai sur la théorie des eaux courantes. Du Boys. Annales des Ponts et chaussées, 1879.

become more marked, because the difference between the two banks will continue to increase until the talus of the convex side shall have assumed an incline sufficient for the force of gravitation to stop the cross movement of solid matter.

If the bed is very wide it may happen that the energy of the cross current is insufficient to effect the transport of the solid matter over its entire width as far as the convex bank; the deposit will then take place before arriving at this bank, near the middle of the bed, and two *thalwegs* will be formed, the principal one in the neighbourhood of the concave bank, the secondary one near the convex bank and separated from it by a bar lying in almost the same direction as the banks.

If on the contrary the energy of the cross current is sufficient as regards the width of the bed for the removal of solid matter to be effected as far as the convex bank, there will be but one *thalweg* in the neighbourhood of the concave bank, and the transverse section will acquire a form similar to that of a triangle the base of which is formed by the surface of the water and the apex is on the line of the *thalweg.*

If the bend in the river is very sharp the deviation will be very pronounced and the energy of the cross current very great; consequently exactly at the foot of the concave bank the bed will be deep, while on the convex bank the deposits will be considerable and capable of keeping their position upon a fairly sloping incline; the convex bank will advance and contract the bed as it becomes dug out. That is to say the channel will be deeper and narrower and the *thalweg* nearer the bank in proportion as the curve of this bank shall itself be sharper.

Moreover it is clear that similar effects will be produced along any resisting obstacle or sharp projection against which the current shall be directed, produce a deviation and lose a portion of it force. The intensity and extent of these effects will depend on the length and direction of the obstacle or bank and also on its form.

If the resisting bank has a very gentle slope the rising water will be disposed of without difficulty, the deviation will be hardly perceptible and the deepening of the bed inconsiderable. If on the contrary the resisting bank consists of a steep slope or is perpendicular like a wall, a dike or a wall of rock, the rising water is confined, the deviation is sharper and the deepening more considerable. Finally, if the obstacle is very high the same effects will be produced whatever the condition of the water may be, that is to say the same in time of flood as when the water is at its average level, and they will be the more marked as the forces at work are more considerable.

Every obstacle, every oblique or concave resisting bank therefore has the effect of deepening the bed in its neighbourhood, and the more so as it is more resisting, abrupt, perpendicular or oblique or has a sharper curve or greater height; and as it constitutes a permanent cause, at least

relatively, its action will not only occasion an increased depth but will also maintain it.

It remains for us to examine what takes place in the longitudinal section. It can be conjectured that the same causes which produce sinuosities and an inequality of depth in the transverse section will have a similar effect in the longitudinal section and will prevent a uniformity of incline.

The distribution of depths in the transverse section depends upon the resistance of the bottom, and at the same time upon the form and nature of the banks which modify the movement of the water and effective force of the current. These circumstances are not the same in all sections and consequently the maximum depths with not be the same and will not occupy the same positions. On the other hand as the sinuous form draws the current from one bank to the other, each bank will alternately present points where local conditions help to maintain the depths and will consequently be unfavourable to the formation of deposits. From which it results that when after a flood the solid matter stops, it is between these points, generally in passing from one bank to the other, that deposits will be produced, of which the form, importance and set will depend at once on the local conditions and the peculiar nature of the flood.

Therefore after the flood has passed and the movement of solid matter is suspended the profile of the *thalweg*, the *locus* of points where the bed is alternately deep and shallow, will be composed of a series of inclines and counter-inclines fluctuating from one side to the other of the mean incline of the water-course. And the bed will consist of a succession of hollows sometimes near one bank, sometimes near the other, and separated by ridges of which the form, height and set will vary from one point to another.

Regular observation confirms this induction. All the soundings taken in a river indicate this form, and it becomes perfectly apparent in rivers with a variable discharge when the volume of water becomes very small. And if the discharge becomes absolutely *nil*, as happens for instance at the time of low water in a secondary branch fed only at the average water-level, instead of an absolutely dry bed, as would be observed if the incline was uniform or always in the same direction, a series of small lakes is met with, filled with smooth water and separated by perfectly dry bars.

To a more or less marked degree this form is met with in all rivers and the flow actually occurs as in artificially dammed rivers. The form of the bottom reacts upon the profile and the ledges cut up this profile into a series of reaches with gentle inclines separated by rapids. This form is especially met with at low water; in proportion as the water rises the ledges becoming more and more submerged disappear and the local irregularities are toned down. Moreover, they are the more marked

as the general incline of the water-course is more pronounced, the discharge more variable, the bottom more unstable and its accidents more decided.

Nevertheless between rivers artificially dammed and natural water-courses there is another difference besides the magnitude of the effects produced, namely that in the former the position, the set and the height of the dams are absolutely fixed, while in the latter they are variable.

In fact if we consider the moment in which the discharge is sufficiently feeble for no movement of solid matter to be produced, the form of the bed and the situation of the ledges will not vary as long as the water does not rise. But when a flood occurs the effective force of the current will become sufficient to put the materials in movement, the form of the bed will change and its disfigurement will increase to the maximum; then when the water subsides an inverse change will take place which will contiue until by the decrease in the discharge the effective force of the current will everywhere become inferior to the resistance of the bed, all movement of solid matter will cease, and the form will change no more. By this time, the solid matter which carpeted the bed before the flood and which was carried away during the rising of the water will be replaced by that which has been brought down and deposited as the water subsided; but it may be that the quantity and position are not the same. In fact all floods are not alike, but differ in nature and importance; in some diluvial tributaries predominate, in others peaceful tributaries. Each one finds before it a different bed to the floods that have gone before and has a different flow while rising and falling. After it has passed it will leave, like those that have preceded it, a sinuous bed formed of a series of channels separated by ridges, because for this general character to be produced it is only necessary that the uneven resistance of the bed shall remain a permanent cause in spite of the variety ot the floods; but it is evident that the form of the bed, the direction of the banks, the varieties in depth, the position, set and relief of the ridges will be modified.

These modifications will be more or less considerable according to the differences presented by successive floods, and according to the differences they meet with in the form and resistance of the bed and the banks.

For this reason after every flood continual upheavals are met with on most natural water-courses, while on the contrary in those whose banks are absolutely constant and determine by their form the position of the different depths, the form of the bed changes little in ordinary floods, the variations in depth are reproduced in places favourable for their formation and the deposits always reform in approximately the same place, varying only in their set and relief according to the nature and quantity of the solid matter in movement.

This comparative constancy constitutes a considerable improvement for property along the river-banks, but an insufficient improvement for

purposes of navigation; for the chief difficulties consist precisely in the relief and set of ridges that must be removed, but it simplifies the problem and in many cases allows of a satisfactory solution.

We will confine ourselves to these general observations which might easily be developed and extended, but it is sufficient to draw attention to some of the essential facts when regulation works are to be undertaken, and we will summarise as follows:

1. *Natural water-courses carry down solid matter with the water. The quantity of this matter depends on the resistance offered by the bed and the soil composing the basin; it increases, all things being equal, with the volume of water and the incline.*

The movement of the waters is periodical; they pass from a feeble to a greatly increased discharge, once started they continue their movement without stopping until they reach the sea. The movement of solid matter follows that of the waters, but instead of being continuous it is intermittent and is effected by stages.

2. *The form of all water-courses is sinuous, consisting of a series of curves and counter-curves which are connected more or less abruptly.*

3. *The depth is unequally distributed in the cross section, being greater in those parts of the bed which offer least resistance to the current. Resisting or sharp projecting obstacles a*

4. *The profile*
but a certain nu
determined by
composed of a
line as they ap
rising and falli
distribution of r

5. *The bed i*
form is the m
it is especially
marked and the
the discharge in

6. *Every flood*
bed and modifies
character, the s
differs from it
sinuosities, the
of the ridges.

But when in
floods only modi
have passed the
ledges reform wh

II.

Regulation Works.

CONFINEMENT OF THE BED.

The first operations effected on rivers are ordinarily for the protection of property against the crumbling away of the banks and against inundations. They consist in the building of revetments along the banks, groins to draw off the current from the banks and dikes to prevent overflowing. But as they have been undertaken in different epocs, often in ancient times, without any methodical plan, without being viewed as a whole, they have not as a rule increased the facilities of navigation and sometimes have even created obstacles.

Regulation works properly so called, and in general all works of which the main object is the improvement of the condition of rivers with respect to navigation, have only been attempted within quite recent times and were not carried out to any large extent until the opening of railroads. The regularity of transport which has been the result has become an imperative necessity to trade, and it is now essential to take means to render it possible upon navigable ways by improving their form, increasing their depth and lengthening the period during which they may be used to advantage.

The problem is therefore comparatively new. Wherever it has been possible it has been found perfectly satisfactory to canalise rivers by means of moveable dams. But where various reasons, the examination of which would lead us astray from the subject which occupies us, have made it desirable to abandon this means for the regulation of the free course of the river, the problem has become much more difficult and the solutions of it less complete and still susceptible of numerous improvements. This gives a real interest to the examination of the attempts that have been made and to a knowledge of the results obtained.

In regulation works, such as are generally effected, it is usual to commence by gathering into one bed the water in the false branches. Irregularities in the banks of this single channel are next removed, the sharpness of their outline is smoothed down and it is endeavoured to give their form, as far as regards their greatest depth, a direction that may easily be followed. We seek therefore, especially by confining the waters within the summer bed by constructive works sufficiently near together, to obtain

a flow with the requisite depth by the double effect of the swelling produced by the contracting works and of the more energetic action they exercise in wearing away the ridges and scouring the bottom.

The first operation requires no particular observation; the necessity of it is evident. Navigation is generally easy when there is a fair quantity of water; difficulties only commence when the discharge decreases. The first condition therefore is to lose nothing that can be disposed of and to gather into the channel of navigation all the water in the river in the dry season.

The regulation of the form of the banks is a much more delicate operation, first because local circumstances often occasion considerable inconvenience and because the expense is much less and the result more certain when too great displacement of the bed is avoided.

In some rivers the form is simply composed of arcs of a circle connected by straight lines, in others a sinuous form or a system of continuous curves has been adopted; but whatever the forms adopted may be they are nearly always sinuous and must conform to certain general principles dictated by experience.

Long straight reaches give rise to an uncertain and variable *thalweg*; moreover by decreasing the distance they increase the incline and the speed and are detrimental to the formation and maintenance of a deep channel.

On the other hand sharp curves fix the *thalweg*, but they determine the formation of a deep and narrow channel, a circumstance which as well as tbe sharpness of the curves renders the passage of boats very difficult.

Curves of large radius offer neither of these inconveniences and on this account they are generally adopted when possible. However, without it being possible to formulate precise rules, there are certain proportions it is well to observe between the width of the bed, the radius, the length and the height of the curves. If for instance the height taken between the top of the curve and the tangent common to two inverse contiguous curves was less than the width of the bed, a direct current might form between the constructive works and the channel being insufficiently guided would be inconstant; in general the condition necessary to avoid this inconvenience is found naturally fulfilled in the comparatively narrow summer bed, but it is necessary to consider it with regard to the winter bed which is much wider, because a defective direction in the main current of the high waters might occasion very serious disturbances in the channel of the low waters. In the same way it is necessary to prevent the current when it abandons one concave bank, that is to say the direction of the tangent at the point where the direction changes, from running into the opposite bank where it is convex; this latter would be attacked if it was not protected and the form of the bed would be dis-

torted; and even if it were protected deep places would form none the less at the foot of the protecting works and these would also cause distortion in the channel.

The conditions necessary, together with the local circumstances that have to be submitted to, generally indicate the solution to be adopted for the form of banks within rather narrow limits, between which there remains however a certain latitude. It is necessary to take advantage of these conditions to give the banks the most suitable form for the satisfactory distribution of the variations in depth.

General experience and the precise observations of M. FARGUE upon the Garonne have clearly shown the superiority of continuous curves in this respect.

Finally the most difficult question remains, namely the determination of the distance between the banks or of the mean width of the normal profile corresponding to a given discharge.

This width is calculated by means of the well known formula for permanent movement in open canals:

$$R\,i = b\,u^2$$

in which i is the mean incline of the river throughout the part under consideration and where the discharge is the same, u the mean speed and R the average radius *) which in large water-courses differs little from the mean depth.

As to the coefficient b, sometimes that which results from experiments which have gone to establish the formula is adopted, choice being given to those experiments in which the nature of the walls of the canal used for them resembles as nearly as possible the conditions met with on a river; at other times for the sake of greater precision it is determined by direct experiment on the water-course in question.

So that if $L =$ mean width required and $Q =$ discharge of that part of the river under consideration,

$$Q = L \times R \times u$$

and therefore

$$L^2\,i = b\,\frac{Q^2}{R^3}$$

where all the letters represent known quantities if the mean depth R be determined.

Sometimes the depth of water it is sought to obtain is simply taken for the value of R, or by an examination over the whole river where the discharge remains equal to Q a mean depth R_1 is sought for by making

---

*) If Ω is the section and χ the wet perimeter $R = \dfrac{\Omega}{\chi}$

calculations upon a great number of sections; at the same time the minimum depth t is taken, naturally on the same section of the river, and the mean depth R is thus obtained; this is to be introduced into the formula for the determination of the mean normal width from either of the following equations in which T = depth of water required:

$$R - T = R_1 - t$$

or

$$\frac{R}{T} = \frac{R_1}{t}$$

which are evidently both arbitrary.

The width of the section being thus calculated, the bed it is required to create may be confined either by dikes running parallel to the course, or by cross works which at intervals determine the normal profile. The choice between these two methods depends upon circumstances. On rivers with a considerable incline leading dikes are generally employed, on others preference is generally given to cross works. Where the nature of the materials to be disposed of makes it desirable to use stone for these structures dikes are most generally used, but the contrary is the case when it is a question of fascine-work which is more easily placed crosswise than the other way.

Dikes guide the current better when the speed is great; groins more easily provoke accretion; but the great advantage which the latter present when they can be employed is that by lengthening them it is easy to modify the profile adopted in the first instance. It is easily understood how uncertain is the determination of the width by the formulae that we have given; the variety that we have pointed out in the manner of applying them would be sufficient to show the many chances of error which their use entails. These errors are much more easily corrected with leading dikes than with cross groins, for it should be remarked that when works of this nature are constructed to modify the width of the profile adopted, it is nearly always with a view to contracting it and this may be due to many causes: either from motives of prudence a very marked contraction has not been made in the first instance, or it has been necessary to construct the projected works at a comparatively high level and the profile has been established for the discharge at the average water-level, and when the water is low and the works should come into play, they remain separated from the channel which not being confined by them fluctuates in the gap between them; or again it is recognised that they have not fulfilled the expections formed of them, that the depth it was sought to obtain has not been reached and it has become indispensable to try to increase it by resorting to further contraction. When the channel is confined by dikes there is no other resource than to build new ones, a method which

presents many inconveniences besides its expense; with cross groins the modification of the profile may be satisfactorily effected at a moderate cost, because it is sufficient to lengthen the groin at low water-level, which in reality produces two distinct profiles — one for low water and another for the average level. This very rational system is met with on many rivers, having either been adopted in course of time or introduced since the commencement of the works.

But this advantage however real it may be could not give the cross works the qualities they want for certain purposes and especially for guiding the current into the sharper concave curves and more considerable inclines; therefore in a great number of cases a mixed system has been adopted in which each kind of work has been employed wherever either was found most suitable.

Such are the main characteristics and rules most followed for regulating by means of the confinement of the bed. The application of the method on different rivers presents very sensible differences, both as regards the principles which regulate the forms of rivers, the methods of calculating the normal profile and the choice of the works by which the confinement is effected.

But whatever these differences may be the principle remains the same, viz. to determine with reference to the known incline and discharge the profile corresponding to the flow with the requisite depth and to induce the regulated course of the river to follow it throughout, as long as the discharge remains the same, either continuously by the help of leading dikes, or by the placing of groins at intervals.

Thus by gauging the river as it were and fixing the normal profile, which would be found in a channel with a regular incline and constant depth, we endavour to provoke this regularity of incline and depth.

This method was for years adopted on the Rhône to the exclusion of nearly all other systems up to 1882. It has often given excellent local results and it would be easy to mention many important sections on this river which have been greatly improved by it and the success of some has even been greater than expected; but it has also occasioned numerous mistakes and these mistakes have become more frequent in proportion as the works have been more extensive and it has been possible to judge well of their effect, not only on the rectified portion, but also on the neighbouring sections. This effect which is nearly always detrimental is the same when a small portion of the river is regulated or a considerable distance is included in the improvements. And it is easy to see that it could not well be otherwise considering that the principles upon which the works are arranged are the same.

From the explanations given by us in the first part of this Report it results that the bed of a water-course consists of a series of comparatively deep hollows separated by ridges or ledges; the profile of the water

presents but a slight incline upon the hollows and a fall upon the ridges. The depth of water is always less upon the ridges and it is these that give most trouble and must be regulated. To increase the depth which is insufficient the ridge is enclosed for a certain distance above and below by works which reduce the width of the bed, as has been said above, to the dimensions calculated, which correspond to the flow with the requisite depth. If the bottom is resisting our expectations are realised and the estimated increase in depth is approximately obtained, but such is not generally the case; if the bottom is unstable, it is composed of matter which, where the confinement is effected, the water is no longer able to wash away after the floods have subsided on account of its depth and incline.

The confinement modifies the state of things to which the formation of the bed is due and by increasing the depth the effective force of the current is augmented, the bottom is scoured, the ridge is removed and the requisite depth is obtained and often even surpassed; but at the same time the bar disappears which retained the water in the hollow above it, and this hollow also disappears. What takes place in this case is precisely analogous to what happens in a canalised river when a dam is lowered — the obstacle disappears, the water of the reach sinks, and the fall is added to that of the dam above, unless in the interval there is a natural ridge which, submerged when the dam is raised, will after it has been lowered form an intermediate bar and distribute the fall effaced by the dam above. In the same way the removal of a shoal increases the fall of the bad passage immediately above and makes it worse; it often also uncovers intermediate shoals which, sufficiently covered before for them to offer no inconvenience, make their appearance and in turn become difficult passages.

However these effects may be reduced by those which take place below the works. The solid matter taken from the shoal is carried away as long as the effective force of the current is sufficient; when this decreases they are deposited, ordinarily where first the width increases, either immediately below the works or in any other favourable spot; a new shoal is formed and the resulting bar may partly take the place of that which has been suppressed and compensate to a certain degree the lowering of the level of the water.

But as the profile of the course of a river is formed by a succession of steps, when one is suppressed either one or other of these consequences is the result: either the step suppressed is developed elsewhere, or its height is added to one of those in the immediate neighbourhood, or it is distributed among them; but finally either the same number of steps remains, their position only having changed, or there is a smaller number and the height is increased. The resulting improvement where

the shallow has disappeared is compensated by an aggravation at one or several other points.

For it to be otherwise it would be necessary for the ridge suppressed to be replaced by an incline the total height of which should be the same as that of the ridge, that is to say that the two reaches which were separated by the ridge should be replaced by a channel with a regular incline which would extend from the upper to the lower ridge.

The necessity of obtaining this result, if it is desired to obtain real improvements by the process of confining the banks, renders the regulation of the incline on rivers where it is attempted a matter of such importance. This necessity also soon leads to the impossibility of confining the regulation simply to the part affected by the bad passage, but requires the prolongation of the works, both up and down stream, over the whole length of hollows contiguous to the ridge, and from point to point, from one ridge to another, systematically throughout the course of the river.

It is in fact natural to suppose that the various parts of a river are in some way severally answerable for its condition, to attribute these inconveniences to works partially effected for their isolation, and to think that by everywhere following the lines pursued where good results have been obtained these results will be generalised.

It is still more natural from a technical point of view to say that if the water flows over different inclines the fact is connected with the diversity of the profiles, and that by regulating the profile the incline will also be regulated, and to hope that the lowering of the water resulting from the suppression of a ridge may be compensated by the swelling produced up stream by the lengthening of the confining works and by forcing the water from the hollow to flow into a narrower section at a greater incline.

This argument would not raise any very serious objection if the bottom was stable, but as it is unstable what actually takes place is very different from this; the new conditions under which the water flows occasion modifications in the form of the bed, and the new form which it assumes will in turn influence the conditions under which the water flows.

Let us consider a long section of a river confined by regulating works. The first effect of confining the bed is to increase the incline and the depth, and the flow continues as though the bottom was fixed. But the form that the bed presents at this moment and the nature of the materials which constitute it are such as suited the circumstances anterior to the erection of the works and which at a certain moment in the fall of the water had realised an equilibrium between the effective force of the current and the resistance of the bed. This equilibrium is upset by the modification in the conditions under which the water flows, the effective force increases throughout the confined section and the bottom

is attacked; but as the incline has changed the depth has increased more up stream than down stream, the increase in the effective force is more considerable and the scouring more energetic; the water becomes charged with a greater quantity of matter than it is capable of carrying to the end of the dike, so that it is gradually deposited down stream, the bottom of the bed is dug away up stream and is raised down stream. This distortion acts upon the profile of the water, the incline of which decreases, and this effect will continue to be produced until the reduction of the incline shall have caused a sufficient decrease in the effective force of the current for a new state of equilibrium to be established. If as generally happens the successive layers of alluvial deposit which are uncovered by the scouring do not present very different resistances, the incline will become less than it was before the regulation, a condition necessary for reducing the effective force to its original value, since the depth having become greater the volume of water which acts on the bed has become more considerable.

Thus while on one resisting water-course the confinement produces an increase in the incline, on a river with an unstable bottom on the contrary the confinement occasions a decrease in the incline. Throughout the contracted section, if the conditions of the form of the bed are satisfactory, a channel may be obtained with a direction more easy to follow and of greater depth, that is to say a combination of circumstances more favourable to navigation; the improvement may even appear the more complete as the depth obtained is frequently greater than expected, for the increase depends both on the decrease in width, which was taken into account, and the decrease of the incline, which was not taken into account.

This modification of the incline moreover is not effected rapidly; in time of low water, although there is a sensible scouring action, it is inconsiderable; it only becomes more pronounced in time of floods; as at first it had increased plenty of time might pass before its decrease might entail detrimental consequences; but in the long run the modification becomes more marked and its effect is felt at both extremeties of the section confined, where the increase in depth becomes evident.

The experience derived from the works formerly erected on the Rhône after this system has several times exemplified this consequence of regulating a river by the confinement of the bed; but although it has been observed elsewhere and already noted by a certain number of authors it does not appear to be universally known; we therefore think it may be of service to give an example of it which we will choose from among the works which, regarded simply within their limits, have produced a certain and incontestable improvement. (Plate I).

Between the confluence with the Ain and the confluence with the Saône the Rhône has a course of 35 kilometres. The physical conditions

met with before regulation were the following. Throughout the 10 km. below the confluence with the Ain, from this confluence as far as the neighbourhood of the village of Sons, the waters were united almost continuously in a single branch along the hill on the left bank, the right bank consisting of plains which became submerged in time of high floods.

Throughout the 8 km. above the confluence with the Saône, which form the channel to Lyons, the waters were equally united in one bed. Navigation in these two sections where no regulation had been effected encountered conditions which were certainly difficult, but incomparably less so than in the intermediate section.

In the latter, over a distance of 17 km., the stream spread itself over a surface which in some places was nearly 6 km. wide and was broken up into numerous branches; on some profiles as many as eight could be counted, among which the discharge at low water was distributed unequally. The main branch followed by the navigation changed its position incessantly, at every flood in fact, and even in an almost constant manner under the action of the mean waters which were sufficient to carry down earth which was constantly moved and was therefore most unstable.

The improvement of this channel was undertaken according to the method the main lines of which we have already indicated. At first a project was studied in 1847 which consisted in separating the navigable branch from the false branches by a dividing dike at the entrance and in building a dam in front of the village of Thil across the principal false branch where nearly all the other branches began; next a channel was opened across the plain over its whole length of 17 km., the normal profile of which was calculated to give a depth of 1.60 m. at ordinary low water. The form of the channel, studied with the greatest care, was composed of a succession of very rational curves and counter-curves. The expense however was very considerable and the project had to be abandoned for another which, while it preserved the works of separation and the same normal profile, applied this profile to a less expensive form of bed and included the branch named Miribel, also regulated, at that time used for navigation.

The works were carried out according to this programme and finished in 1857; the resulting improvement was very evident and the navigation, in place of the continual uncertainty in which this passage left it, found in the canal of Miribel a channel easy to follow and of sufficient depth at any time of year. For several years this improvement appeared to be the only result of the works and nothing indicated that they could have any inconvenient consequences. Nevertherless the bottom of the canal was attacked; lower measurements began to be registered at low water than before the works were executed and these got lower and lower,

while at the exit they marked higher and higher; then the foundation of the works, which had been made at low water-level, appeared in the upper portion of the canal and was even uncovered at the mean summer level of the water, while below the same water-level the tow-path was submerged and became useless throughout the greater part of the year. It became necessary to improve this situation which might at any time become very serious. The tow-path was first raised over half the length, that is the part submerged; then to arrest the movement it was decided to lower the dividing dike and to cut down the dam of Thil as low as possible, in order to allow the greatest possible volume of water to find its way through the false branches, not only in floods but also at the mean water-level. It was supposed that by this means the main branch would be relieved and that by decreasing the volume of water which crossed it its scouring action would cease. The result aimed at has bien partially realised; the movement of the profile has become much slower, but has not entirely ceased; and although the volume of water which passes into the canal has become notably less, the incline which will set up any equilibrium between the resistance of the bottom and the effective force of the current under the new conditions of depth has not yet been attained.

Plate I gives the projection, the profile lengthwise and three transverse sections before the works were built, and in its present state. The profile on a large scale only gives the regulated section; the profile on a small scale extents from the confluence with the Ain to Lyons and shows the junction of the old and new profiles at the two extremities. The first indicates the mean incline for every kilometre, the second the mean incline for every five kilometres; the scale did not allow of more detailed indications, but the actual profiles are far from giving regular inclines over these distances and they take, like all the profiles which we have had occasion to refer to, the form of a flight of stairs, a profile which the bottom gives rise to.

A glance at these profiles, in which the surface of the water and the bottom are indicated along the line of greatest depth, suffices to show clearly the movement down stream of a portion of the matter composing the bed, the decrease in the incline of the bottom and the decrease in the incline of the surface which has been the necessary consequence.

We will briefly recapitulate the results that these works have given. In the canal itself a direction much more easy to follow has been obtained and also a greater depth. The plan of 1847 shows that the curve where there is a depth of 1.20 m. below low water mark is in several places interrupted and the minimum depth in the channel of navigation is 0.80 m. or 0.90 m. The plan of the present state of the river shows on the contrary that the curve of 1.40 m. is not interrupted; nevertheless this depth cannot be fully utilised, because

it is not found everywhere over a sufficiently wide area and because it is not met with in all the profiles where navigation is possible; in fact a depth of about 1.20 m. or 1.25 is the greatest available, which however is a great improvement on the original state of the river. The mean depth in the canal when the water reaches the discharge upon which the calculations of the project were based is more than 1.80 m.; it is greater than was expected, which is not surprising as the incline is considerably less; the average depth at the time the water is lowest is still 1.50 m., but it is very irregularly distributed; from one section to another it varies from 1.20 m. to 2.20 m.; as to the extreme depths they vary from a maximum of 4.70 m. to a minimum of 0.50 m. measured at 30 m. from the bank. The form of the profile is sometimes a rectangle, more often a triangle the apex of which is alternately near each bank. Finally the profile realises neither the incline nor uniformity that was anticipated. The mean incline throughout the length of the canal is 0.696 m. per kilometre; it varies from 0.41 m. to 1.09 m. per kilometre and the local incline varies from 0.20 m. to 2.20 m. per kilometre.

Thus in spite of the improvement realised, in spite of the enormously extensive alterations that the river has undergone while passing between the constant banks, neither regularity in the cross section has been obtained, nor constancy in the mean depth, nor uniformity in the incline; and the bed that has been opened remains formed as everywhere else of a series of hollows separated by ridges, while the profile presents a series of reaches with a comparatively feeble incline separated by falls.

Outside the canal the general incline of the combined streams at the entrance to Lyons, at kilometre 5, where the profiles join, has not sensibly varied; it was and still is 0.81 m. per kilometre, but its distribution has changed considerably. Throughout the canal, from kilometre 8 to kilometre 25, it was 0.883 m.; it is not more than 0.696 m. per kilometre on the other hand above the canal; from kilometre 25 to kilometre 34 it has been raised from 0.75 m. to 0.96 m., and below kilometre 8 to kilometre 5 it has been raised from 0.49 m. to 1.06 m. per kilometre.

Navigation has become very difficult in the channel, but it has become most difficult at its extremities, where not only the speed is very great, but the depth at times of low water is less than 0.80 m., which stops navigation as formerly the difficulties of the plain of Miribel did.

If would seem natural to continue both up and down stream similar works to those which have given throughout the canal so great an improvement, and the continuation of them up stream has in fact been effected; but as similar results have been produced in consequence in many places, it has been necessary to recognise the fact that the lowering of the incline was an inevitable consequence, that has long been

taught by experience, of the contraction of the section; the same method has not been pursued and as we have said more attention has been given to works which might be able to lessen or remove the evil than to those which simply risked the changing of the position of it.

The causes which provoke the decrease in the incline are independent of the length of the section confined; the only difference which appears possible between a long regulation of this nature and a short one is that the decrease in the incline corresponding to one and the same resistance in the bottom will give at both extremities a greater fall in the first case than the second; but there is no reason for us to believe that the bottom will be better maintained with the original incline, when the depth and scouring action of the water will be increased by the decrease in the width if the works embrace a large portion of the river, than if these works are confined to a shorter section.

This grave inconvenience cannot be obviated by works of this nature, except by increasing the resistance of the bottom at the same time as the effective force of the current which acts upon it is increased. It is a very simple idea which all engineers should have who have occupied themselves with these questions and who have been in a position to make the observations we have indicated; it has been applied upon a certain number of rivers, and upon the Rhône itself it is very old.

The employment of works, not only on the banks to increase their resistance or modify their form and pitch, but on the bottom to increase its resistance, to fix or modify its inclne, has been proposed since 1842 for the regulation of the rapids at Sault.

The project consisted in covering the falls by the eddy produced by raising the incline down stream by means of a series of bars or submerged ridges; and the inventor, M. Goux, C. E., from the effect of these works was able to make very clear explanations which have lost nothing of their value and their generality. We will state them briefly.

Let us suppose that it is sought to establish over a certain distance on a river a given incline which shall differ little from the natural incline in other parts of it. If this distance be divided into equal parts and a bar or ridge be constructed at each point of the division so that a line along the tops of these ridges shall have precisely the requisite incline, the levelling down from one ridge to another will be equal. Let h = their common value.

A series of reaches will thus be formed identically similar, separated by similar bars, and if the discharge of the river becomes so small that in each reach the speed and superficial incline are almost *nil*, the difference in level between two consecutive reaches, that is the fall from one to another, will be constant and equal to h. Now if the discharge increases, an incline will be established in each reach and from one to the other a different fall than that which previously existed, but all the ridges

being subject to identically the same conditions the variations in the surface of the water will be reproduced in a similar manner from one to the other, the inclines in each reach will be equal, the falls on each ridge will be the same, and the difference in the level of the water between two consecutive ridges or between any two points separated by the distance equal to the space between two ridges, will be constant and equal to h.

This constant difference in level consists of the total incline of one reach and the fall of the next reach, so that if p = this incline and c = the fall,

$$h = p + c$$

from which it follows that:

1. The difference in level between two consecutive ridges is the maximum limit of the fall from one to the other.

2. This maximum fall is not reached unless the discharge is so small that p becomes *nil*.

3. So soon as this condition ceases, the height of the fall c becomes less than h and decreases as the incline of the reach is more pronounced; so that as the discharge increases a moment will arrive when p will equal h and then all fall will be obliterated on the ridges and the incline of the surface of the water will be regular, as though the bed formed by the series of ridges was continuous.

Moreover it is evident that the equidistance between the ridges, which we have admitted to simplify the argument, is not indispensable and the falls would be effaced even if this equidistance was not maintained.

Experience fully confirms these inductions and continually shows that the fall produced upon a ridge, when the discharge is inconsiderable, becomes less and less until it disappears entirely in proportion as the discharge increases. Falls of 0.50 m. or more which are frequently met with on fixed bars in time of low water, are entirely obliterated when these bars are covered with two or three metres. The incline on rivers is always small, so that it is sufficient to place the ridges at suitable distances from one another to reduce the height h, maximum in a fall when the discharge is very low, to a very small quantity, and consequently to make sure that when the ridges are covered with a depth of water equal to that required for navigation purposes, it will no longer cause any appreciable undulation on the water's surface.

This depth of water sufficient for effacing the falls would also be sufficient to counteract every other inconvenience, if the ridges could be executed in masonry with a surface perfectly smooth like the sills of a lock; but the excessive expense would make the use of them in most cases impossible. They can generally only be used when they cost little and, with the only known economical means of constrution, their surface remains irregular; under these circumstances they may become dangerous to boats and may also cause eddies calculated to interfere with

steering; and for these two reasons prudence obliges us to keep them below a greater depth of water than the maximum draught and to place them lower than would be necessary to obtain the requisite incline.

The project for the correction of the falls of Sault, for which they were proposed for the first time, has not been carried out; various reasons have tended to give the preference to the formation of a branch stream with locks; but since then sunken groins have frequently been employed upon the Rhône; experience has shown that by placing the top of them at least 2.50 m. below the lowest water-level they present absolutely no inconvenience. Experience has also shown that the use of them for procuring a greater regularity in the incline, an object first aimed at in all works of this sort, only gave very inconsiderable results; but it has enabled us to see that much benefit could be derived from the regulation of the bottom and the prevention of scour. It has also proved that by establishing them in certain conditions other very important effects could be obtained, complete explanations of which we will furnish later.

However, in certain special cases, the groins being kept at this depth, we have been able to make sure that they have produced an appreciable effect on the incline and a slight rise in the level of the water. This effect has been especially marked when they have been employed to counteract a fall caused by a sharp obstacle, such as some old artificial works, a bar of rock etc.; but different and much more complex conditions are then presented than in the flow of water over a ridge of gravel. The form of the latter is always rounded off, its slope up stream and even down stream has a very slight incline, so that the depth increases progressively and slowly all along the top. A bar of rock on the contrary is a sharp obstacle, invariable in form and position, while at the foot of it the soil is unstable. These bars are nearly always followed by deep hollows, so that the water which falls over them descends abruptly to a considerable depth to rise again further on; in most cases the surface of the water presents a very apparent rise and this phenomenon is particularly noticeable below a passage confined by two obstacles close together, such as the piers of a bridge. By establishing in the hollows a series of submerged ridges below the obstacle, not only is the deepening arrested, but a barrier is opposed to this plunging action of the water, it is forced to expend itself on the surface and the rise, the main cause of excessive inclines, is decreased and sometimes even suppressed. Many important improvements have been thus effected under very different local conditions. We will mention only a few instances. On the Rhône at the entrance to Lyons some old works composed of piles and hewn stone produced an abrupt fall with very dangerous eddies; a few ridges have entirely done away with the fall and have completely suppressed the tempestuous movement of the water. On the same

river near Bourg-St Andéol there was a bar of rocks which caused a rapid which powerful steamboats could not ascend without being towed up; the placing of a few ridges below the rapid has sufficiently reduced the fall for the heaviest laden vessels now to pass over it with the use of their own power alone. On the Saône, the bridge of Ainay, the arches of which are narrow and confined with rocks, at times of high water presented some difficulty to navigation on account its arch; the same method has given similar results and boats which were unable to pass the arches are today able to do so without serious difficulty.

But except in these exceptional cases groins or submerged ridges, laid down under conditions dictated by prudence and experience, exercise but a limited action on the incline; and although they are in many respects of undoubted utility, they do not effect any more than other methods complete uniformity in the incline.

Moreover, even when their execution might be possible at a moderately high level and their action might be more effective they would supply the means for maintaining the incline, for raising it even where the scouring of the bed has reduced it; but they would be without effect on the modifications caused in the incline by the raising of the bottom, and that such modifications might be avoided it would be necessary to bring about such a combination of circumstances that it would be impossible for a deposit to form in any part of the water-course, and this is evidently impossible.

If on a river there was a constant discharge both of water and solid matter and at the same time the bed was not affected by scour, or at least was sufficiently resisting for it not to be attacked by the current under any conditions, a channel might certainly be conceived having a regular width and incline and in which the flow of matter would never be decreased or suspended and the depth would remain constant. But it is not so; on all rivers the solid and liquid discharges are continually variable. Every flood brings down matter from the mountains and stirs up that which the preceding flood had left in the bed. The matter is carried away as long as the volume of water is sufficient; when the water subsides the matter is deposited to be taken up again by the next flood and so on by successive stages until if reaches the sea.

There is not in all fluvial hydraulics a fact which appears to be better established than this intermittent movement and transport by stages of the solid matter. By constructing suitable works here and there a greater speed may be maintained than elsewhere and a combination of circumstances may be created which will prevent the deposit of solid matter; but the illusion one is frequently induced to fall into is that by pursuing the regularity of the profile and the incline the constancy of the movement of solid matter to the sea will be obtained without cessation.

Thus, if it be supposed that an artificial canal has been constructed with

incline and resistance suitable for preserving the liquid discharge with the requisite depth without variation in the form, the end in view would cease to be attained so soon as water charged with matter was introduced into this canal. Above the resisting framework of the bed deposits will be formed in places across which similar phenomena may be seen to develope as those caused on rivers with indefinitely inconstant bottoms; the principal difference would consist in this, that the artificial bottom would be more opposed to the development of hollows than the beds of other rivers, a resistance similar to that frequently met with on natural water-courses where their bed is absolutely unassailable.

Whatever progress hydraulics may make, whatever certainty may be given by the known or unknown formulae which show the relation in their continual movement between the discharge, the incline and the section of a water-course, the assimilation of a river with a variable discharge and unstable bottom to a canal with a resisting bottom, which carries only water, will always fail to realise the results expected if it. Such has been the case upon the Rhône and other rivers and it has been the more marked as the water-course operated on agrees less by reason if its nature with the conditions in which the hydraulic formulae have been established and found applicable.

But although it showed the inconveniences resulting from this assimilation, which frequently was forced, the experiment established more clearly the necessity of certain facts and certain forms; it made the effect of artificial works better known and gradually led to the adoption of them in conditions more conformable to the laws which influence the flow of the current in natural water-courses. We have now to consider the attempt made upon these principles upon the river Rhône.

III.

Regulation Works.

METHOD ADOPTED ON THE RHÔNE.

§ 1. *Explanation of the method.*

The methods that we have concisely explained were employed exclusively upon the Rhône before the law of 1878 and for several years after the passing of this law, which, while creating considerable resources for the regulation of this river, allowed of the works being constructed on a thorough basis such as their assured success seemed to demand.

This immense experiment has caused the abandonment of the system of regulation based on the use of the normal profile calculated as though the bed was resisting and the discharge exclusively liquid, and the renunciation of the possibility of rendering the incline uniform. And it has established as a necessary law in the movement of water and matter in a river with unstable bottom the variable and intermittent flow of gravel and consequently the preservation of ridges and the stair-case-like nature of the profile.

The system adopted therefore no longer requires from hydraulic formulae, which may be sufficiently exact for the circumstances in respect to which they were established, conclusions which could not be so under essentially different conditions. Far from seeking to modify the natural flow of rivers it respects these conditions, and instead of entering into a struggle with nature it seeks to aid her by imitating the manner and form by which she herself in certain cases obtains the desired results.

Observations on the natural form of the bed. — It results from the observations contained in the first part of this Report *that the bed of a river with unstable bottom consists of a series of curves and reaches of various lengths according to the incline of the river, the comparative depth and the incline of the surface being moderate, and that these are separated by ridges forming natural bars and the flow is produced from one hollow to another as over more or less submerged dams.*

These general conditions not only exist on water-courses in their natural state, but they are also reproduced between regulation works in spite of efforts made to avoid them. It is therefore necessary to maintain them.

Their general character, such as we have just defined it, is constant,

but they differ from one point to another in numerous details. If we consider in particular the distance on a river composed of two hollows separated by a ridge or two curves in opposite directions, a distance to which we will give the name of passage, many varieties in the form of passages may be observed; but these varieties may however be grouped in two principal classes.

Bad class of passage. — The first class is met with almost everywhere when the stream spreads itself out and often even when the water is united in one branch, when local circumstances or the presence of defective works favour the continuance of deep water along either bank. The following are its characteristics (Pl. II).

Two hollows run into one another; slight inclines are prolonged over the whole extent of these hollows; the channel passes abruptly from one bank to the other following a direction which more or less approaches the general direction of the banks. The ridge which separates two hollows forms a sharp turn in the current; it constitutes a long dam slightly below the surface and the water flowing over it is shallow and the fall is short. Under the conditions peculiar to the Rhône the depth may fall to 0.40 m. As regards navigation all difficulties are found united in such a passage, namely the want of depth and abrupt change in direction, which renders ordinary restrictions insufficient and requires boats to go round with the help of ropes without their being able to follow the channel and utilise the full depth available, and finally a very violent current.

Passages of this class were formerly very numerous on the Rhône and they put a stop to navigation even before the depth fell below the limit; boats could only pass them when the water was high enough to give the necessary depth in a direction more easy to follow and to reduce the fall by further immersing the dam.

Good class of passage. — The second class was also met with where no artificial works had been constructed, but hardly anywhere except where all the water was united in one branch between stable banks. The following are its characteristics (Pl. II).

Two hollows have their extremities opposite one another without overlapping. The *thalweg* presents gradual and regular curves; the change in direction takes place gradually; the ridge separating the two hollows has an almost normal direction; it consists of a low dam a long way below the surface, above which the water is deep and the fall is distributed. In the conditions peculiar to the Rhône the minimum depth in the hollows in passages of this class varies from 1.50 m. to 2.00 m.; the direction of the channel is easy to follow and the current is moderate; they are easily passed by boats.

Conversion of one class to another. — Artificial works necessary. — With regard to the regulation works which have been

carried out upon the Rhône, all that was done was to convert all the passages of the first class to those of the second, while it was sought to obtain in the cross section a profile of the character and form which is met with in passages which are naturally good.

To obtain this result the necessary operation consisted in:

1st Uniting all the waters into one bed at time of low water;

2nd Fixing in this bed the position of the hollows and consequently of the ridges;

3rd Controlling the formation or set of the ridges.

Concentration of the waters. — To unite the waters into a single channel it is necessary to close the secondary branches. The artificial works necessary for this must have a limited effect on the low waters which alone it is important to concentrate; they should admit of the high waters spreading out over as large a surface as possible so as to reduce the speed and avoid the scouring of the bottom; for this purpose the dam which separates the false branch from the main branch must be cut down to the level at which the concentration of the water is no longer necessary. To make sure of its strength and to decrease the weight it has to support when the overflow takes place, a weight which differs little from the difference of the levels in the stream between the entrance and the exit to the false branch, a series of dams called traverses is laid along this false branch, which divide the total fall and distribute it among them; that is to say that the frame-work of a new bed is formed in this branch the bottom of which is guided by the series of *traverses* and is raised to the level at which the false branch comes into play and relieves the main stream.

Finally it is necessary, especially if the formation of the false branch corresponds to the direction of the current in time of floods, to prevent the main current from becoming established in it at the risk of causing serious disturbances in the channel of navigation; to obtain this result the principal dam, which forms one side of the channel, is joined to the river bank by means of connecting works similar to those which are employed behind dikes and the use and form of which we will indicate later.

Fixing the depth in curves. — We remarked in the first part of this Report that when the banks were durably fixed and presented at certain points conditions favourable for the creation and maintenance of hollows, deposits formed between these points. Successive floods encountering at the same points the same resisting forms produce similar effects and without giving to the hollow identical forms or dimensions, they at least produce them in the same places and consequently preserve the ridges in the same position. The first thing to be done therefore is to make sure of the constancy of this position by determining upon a suitable form for the banks and artificial works to be adopted and to take steps to ensure their preservation.

Experience shows that the depth is easily maintained in the concave curves when no adverse action draws it in another direction, and it is greater and nearer the bank as the curve is sharper. Experience also shows that hollows are formed and remain at the foot of smooth raised banks against which a deviation in the current may be produced, or at least along which the speed ramains considerable under all conditions of water. It is therefore necessary in the form of the works in a curve of the channel to prevent these effects from counter-balancing one another. If the two banks are formed of dikes with smooth steep walls the water will have a tendency to form hollows by both banks, to form a deposit between the two and a passage of the first class will be the result. It might even happen, if the form of the banks is defective, that an accidental circumstance might impel the current against the convex bank where the action of the dike would retain it; and in this case there would be an error in the calculations, the sinuosities of the channel would not follow those of the banks and the hollows would not be preserved in the same places. Instances of this sort are not uncommon where leading dams are adopted. If therefore it is wished to fix the position of the hollows along the concave bank, it is not sufficient to give this bank a form by which it may retain the *thalweg*, it is also essential to treat the convex bank in such a manner that it may be unable to attract or retain the current; that is to say *dikes must be avoided on the convex bank;* it must have the form of a shore with a gentle incline, such as it naturally presents in the good passages of the second class. This form also has the advantage of leaving the space free before the water as it rises and of avoiding the action of confinement, the troublesome effects of which on the preservation of the incline we have already drawn attention to.

Form of the concave bank. — It is generally an advantage to form the concave bank by a dike the continuous action of which is more favourable to the good direction of the current and the repetition of the effects which produce the hollow. The form of this dike has a great influence upon the satisfactory direction of the *thalweg* and the set of the ridges. If the *thalweg* of a good passage is examined, it is found that it gradually leaves the bank at the top of the curve and passes about mid-way between the banks where the change of direction takes place. It therefore presents a continual curve passing from a maximum at the apex to *nil* where the direction changes. The bank should not be parallel to the *thalweg* and its curves should be such that the *thalweg* may be able to leave it gradually as the point where the direction changes is approached. If it was otherwise, if the curve of the dike retained the *thalweg* in its vicinity until the turn was nearly reached, the same effect being produced in the inverse curve of the passage, the change in direction would be abrupt and the passage would more or

less resemble the first class. And as the bank attracts the *thalweg* the more forcibly the sharper the curve is, the curve must decrease in proportion as the *thalweg* removes itself further and further from the dike, that is as it passes in a continuous manner from its maximum at the apex to *nil* at the turn in direction. The observations taken upon the Rhône therefore fully confirm those of the Garonne and clearly establish the advantages of continuity in the form of dikes.

As regards the choice of curves to be employed to realise this condition, there appears to be none that is absolutely preferable and local circumstances often limit the number of possible solutions. Sinuosities and spirals volute have been employed upon the Rhône, as upon the Garonne, but it has been affirmed that for works formed by rocks and constructed often under difficult conditions a sufficient continuity is obtained by simply employing a series of arcs of a circle with radius increasing from the apex of the curve to the point where the direction changes. It is clear moreover that when a concavity is found between two turns the same condition of continuity must be fulfilled on each side of the apex by the different curves which form it.

Considerations of the same kind determine the profile of the dike. The top of it must be placed at such a height that it may retain the waters as long as there is any use in concentrating them for increasing the depth. So soon as this depth is sufficient for the requirements of navigation when boats are fully laden, it is on the contrary desirable to let the water spread over as great a surface as possible, so as to avoid excessive scouring, which is calculated to injure the incline and the width of the channel. In the conditions peculiar to the Rhône this level must not be more than about 1.00 m. above the lowest water-level; they are frequently placed at a higher level, either to facilitate the formation of hollows in the first stage of the works or simply to render the building of them easier, and they are afterwards reduced to the level indicated above. But this level must not be the same throughout the length of the dike. Since the hollows are greater and nearer the bank as the latter is itself higher, it is essential, for the channel to be able to leave it, that the effect of the dike continues to diminish as the turn in direction is approached; and as the curve is reduced the top of the dike is made lower in proportion to the distance from the apex. It should be highest at this apex and is reduced to the natural level of the shore in the neighbourhood of each turn in the curve. We are therefore induced by similar reasons to establish continuity and not uniformity in the profile of the dike.

As long as the level of the water remains low the use of the dike is easily conceived; but when the water rises above the dike, if this class of work is resorted to, absolutely pernicious effects may be produced. The water by flowing over the dike would wash away its foundations; there

would be a risk of its being carried away and of secondary currents being created behind it which might open a new channel; also boats might be drawn against the dike by the cross current caused by the overflowing. To prevent these results the dike is connected with the bank by means of cross works which are called *traverses*, *tenons* or connections. These are run in an up stream direction from the foreshore from which they slope downwards to the dike, so that the combined effect of the incline and the way they are set helps to draw the current into the centre of the principal channel and prevents the formation of secondary currents and the overflow of the water. Their action must be the more energetic as the effect they have to combat is more pronounced, and consequently their incline towards the channel must be the more marked as the water is more violent in its efforts to escape. It is where the curve is sharpest that the centrifugal force is greatest, and therefore the incline of the *traverses* will be sharper. The *traverses* of one group, which all end in the dike at the level which it has where they join, will therefore be formed with different inclines and will rise the more abruptly from the dike the nearer they are to the apex of the curve.

In those parts of the river where the incline is feeble and the bend of the channel is slight, this combination of works may be simplified, the dike may be done away with and simply connecting works may be adopted to direct the flow of the water; but the action of these is less effective, and the circumstances in which this system may be adopted are rarely met with on the Rhône.

Form of the convex bank. — We have remarked how important it is to fix the position of the hollows, to avoid on the convex bank all works or forms capable of causing scour. This bank should be of such a nature as is met with in good passages, that is a shore with a gentle slope so that the water may spread over it without anywhere acquiring sufficient speed to cause scour. When the shore already exists and offers sufficient resistance there is nothing to be done; if the resistance is too feeble it is strengthened by inclined groins which do not rise above the natural level of the soil and which constitute as it were the skeleton of the bed and give it the necessary solidity. If there is no shore, the framework is constructed in the same manner by means of inclined groins which mark the form and direct the water just as the shore would do and thus provoke its formation. These groins should be set so that they throw the main current into the line pursued by the *thalweg;* their incline should be regulated to the same end and they should therefore exercise a more energetic action the further the *thalweg* is removed from the convex bank. The groin corresponding to the sharpest part of the curve must therefore be the most inclined, and on

both sides of this maximum the incline of the groins should diminish till it attains a minimum at the turn in the curve.

Position of the turn. — Fixed position of the ridge. — The rules adopted for fixing a channel in a curve may be briefly summarised: the forms and artificial works most favourable for the formation and maintenance of hollows must be adopted for the concave bank and the same features are to be avoided on the convex bank. The most suitable form must be given to the latter for these effects not to be produced and it must be strengthened so as to prevent all scouring. By these means the formation of hollows along the convex bank is avoided and the preservation of them is assured along the concave bank between the groins, where they will be found regularly after every flood.

If similar features are given to all the curves of the channel the position of all the hollows will remain constant, so that by maintaining the variations in depth along the concave banks the periodical return of deposits is at the same time provoked between two inverse concavities.

To determine the form of the banks it only remains to fix the position of the points where the curve changes and between these points the bends must be distributed in such a manner that they may satisfy both the local circumstances and the condition of continuity, the utility of which we have pointed out.

This position cannot be arbitrary; in fact the points in question are stopping places for matter when the water subsides and the movement of solid matter ceases.

It is clear that we are not entirely at liberty to fix these stopping places and that we cannot without inconvenience and mistakes increase or decrease their number to any considerable extent. The distance separating two deposits depends essentially on the character of the river, the discharge of water, its incline and the quantity and the nature of the matter carried down; these conditions vary not only in different rivers, but also in different parts of the same river; the influence of them on the distribution of deposits is certainly very complex and if it is wished to determine *a priori* by means of these elements the distance between the ridges, we should be led to formulate arbitrary hypotheses and to draw from them conclusions which could not be proved. But fortunately the observation of what passes in any given section of a river furnishes indications which are sufficient for practical purposes; it enables us to affirm when the conditions of discharge and incline differ to an inconsiderable degree that the distance between two ridges is fixed by limits which are not very far from one another. It is between these limits that the distances between the turns in the curves must be maintained by following the lines indicated by good passages and the local circumstances, so that the number of ridges formed

naturally may be approximately preserved, or, if a slight modification is attempted, that this number may be increased rather than diminished, for each ridge corresponds to a fall in the profile of the water and the height of each fall is less when their number is increased.

Such is the combination of conditions to be fulfilled with regard to the distance between the turns in direction, the distribution of the curves, the choice of works, their height, direction and incline. Within the narrow limits depending on local circumstances these conditions determine the form of the banks with sufficient precision and at the same time make sure of the periodical return in the same places of the hollows and ridges.

The set of the ridges. — It may frequently happen that a good form of bed and a judicious choice of artificial works suffice for directing the channel, for guiding it from one concavity to another with easy turns one way and the other, and for giving the ridge such a set and form that it may be a satisfactory shallow easily passed by boats. The continuity of the curve, the height and incline of the artificial works exercise a certain influence on the good direction of the channel. But it may easily be conceived that this action, however useful it may be, may be insufficient.

The curve acts upon the position of the channel on account of the cross current which is the consequence of it, and scouring is the result; the height of the works has a similar effect, the result being always produced in the same direction, that is the hollows are always, everything else being equal, more marked and nearer the bank as the latter is more curved, more even, deeper or higher; but the extent of this effect depends on a combination of variable circumstances, in the front rank of which must be placed the incline of the river and the resistance of its bed, which vary from one point to another, so that two artificial works identically the same in height and form may according to the circumstances in which they are employed determine very different forms of channels.

If in fact two passages be supposed in which the local requirements lead one to adopt the same curves, it is clear that if one of them has a considerable incline on a bottom easily washed away and the other has a slight incline on a more resisting bottom, the effects produced will not be the same. In the latter case the channel will generally be wide, the *thalweg* will be without excessive variations in depth and the channel will keep at a sufficient distance from the bank for it easily to be followed by boats, passing over to the opposite bank with a gentle and gradual turn in direction; the forms will resemble those of the second class of passage and the good set of the ridge will ensure a satisfactory shallow with a gentle fall and will be easily passed. In the other on the contrary the speed will be greater, the scouring

more energetic, the channel narrower, the *thalweg* deeper and nearer the bank, it will keep by it longer and will with difficulty separate from it to pass over to the other bank in a short and abrupt turn; the form will resemble that of the first class, the set of the ridge will be very slanting, the shallow will be feeble, the fall considerable and the direction of the *thalweg* difficult or impossible to follow.

The form of the banks, although it is sufficient to cause the formation of the ridges always in the same place, is not so for regulating their shape and giving them a satisfactory set and formation. It is essential in many cases to increase its effect by means of artificial works intended specially to regulate the change in direction and to effect the gradual transition from the concave bank of one curve to that of the succeeding curve. The comparison between good and bad passages indicates what must be done.

In a good passage the hollows are not excessive and the channel is wide; the *thalweg*, always sufficiently removed from the bank, without difficulty leaves first one and then the other, while the depth gradually decreases as the point where the change in direction is approached. If the form of the transverse section be examined, it will always be found to be more or less like a triangle the apex of which corresponds to the *thalweg* and the base to the surface of the water; the base will be wide and the height moderate; the apex will always be at some distance from the concave bank and the incline of the sides, sharper near this bank, will be inconsiderable. This form of section gradually changes; the height decreases as the apex moves away from the bank; the slope of the two sides diminishes at the same time, but more rapidly along the concave bank, so that it becomes the same on both sides near where the turn in direction takes place. On the other side of this turn symetrical forms are reproduced in the same order.

In a bad passage on the contrary, the channel is narrow and the depth considerable in the neighbourhood of the concave bank; the *thalweg* keeps close to this bank and leaves it with difficulty, passing abruptly to the other; the hollows are preserved nearly up to the change in direction, when they stop suddenly and appear on the other side. The transverse section always has the general form of a triangle, but its base is narrow and its height considerable. The apex is very near the concave bank, is often even at its foot, and the incline of the two sides is very considerable. This form is preserved without much change till the neighbourhood of the turn in direction is reached beyond which without any transition symetrical forms are found.

That the ridge may set well it is therefore necessary to substitute for these defective forms, which the transverse section presents in bad passages, the rational forms which are found in naturally good passages. This result is obtained by placing in deep places sunken

groins and cross dams at certain distances from one another and at a sufficiently low level for them not to interfere with navigation or cause any eddy on the surface.

These groins, while they reduce the depth in some degree, increase the width of the channel. They should be set with a slant from the bank up stream as they are intended to draw off the current; for the same reason they must slope from the bank downwards and the lowest part of them, which determines the maximum depth, determinines at the same time the spot where the greatest speed and the centre of the channel are found. This centre should be nearer the bank as the point under consideration is nearer the apex of the curve; the greatest depth should also be found near the sharpest curves (a little below according to general observation); the groin corresponding to this point will therefore have its foundations lower than the rest, its incline will be greater and its end in the river will be deeper. The succeeding groins will rise higher and higher and their incline will decrease in proportion as the apex of the curve is left further away. Thus successive groins will really cause an inclination in the surface, which will be changed by successive gradations until the normal form is realised; this should be met with at the turn in direction beyond which the inverse of these conditions should be presented.

We are thus led after having realised *continuity* in the form of the channel, the height and incline of the artificial works along the bank, as regards the general form of the river, to also determine the same with respect to the profile of the bottom and the nature of the transverse section.

Sunken groins therefore, employed as has been said, fulfil a double function. They guide the transition from one curve to another and prevent excessive scouring of the bed on either side of the turn in direction. By preserving the ridges and by limiting the depth in the hollows, they preserve the falls and stair-case-like form of the profile, and they prevent the general lowering of the surface of the water, that is to say the objectionable effect which we have referred to and which is so frequently produced when the bed is confined by regulating works. But at the same time by regulating the set of these ridges they lengthen without suppressing the falls upon them and thus make them easy to pass.

The depth at which, on account of the possible imperfection of their construction, the safety of navigation requires these structures to be placed, limits their action on the inclines and this action generally simply preserves them by preventing the scouring of the bed, which would reduce their influence. Experience however has shown in certain special cases that it is possible to attain slight rises in the level of the water above the hollows, and it is clear that this effect would be the more

marked if it were possible to raise the tops of the groins. Such a result would be very effective when from accident and the lack of precautions an inconvenient fall in the level of the water might have been produced; it would be useless, as we have shown above, and would not justify the expenditure of the sum it would require, if we wished to render the incline uniform — a result which it is impossible to obtain. The preservation of the inclines on the contrary is in itself a result both possible and entirely sufficient and the sunken groins, constructed without ordinary precautions, allow of this object being attained with certainty. Frequently further steps are taken to secure the consolidation of the bottom when it is very liable to scour, and it is fixed throughout its width by lengthening the groins from one bank to the other; they are then called bottom ridges and are constructed of wood, having the end turned up stream and reaching to the centre of the channel the position of which they fix by determining the maximum depth in the hollows.

But if the depth at which the groins have to be placed diminishes the effect of them upon the incline of the surface, it exercises but little influence on the effect they have on the current. This action in fact depends especially on the way they are set, the incline of each of them and its variation from one to another, conditions which suffice to determine the distribution of the variations in speed in the cross section, and consequently the order and the form of the deposits. But it is also clear that this ruling action will be the more effective the better the incline of the works, by means of which it is exercised, is regulated, and it is on this point especially that the greatest care must be taken in the construction of the works, for it is easy to take these precautions and costs little to do so.

Flow of gravel. — Relative constancy between the form and the depth. — Such is the combination of rules followed and works adopted on the Rhône since 1884.

The choice of the works employed for the form of the banks in the curved portions of the bed has the effect of ensuring the fixed position of the channel and the preservation of the various depths and of preparing and facilitating the satisfactory transition from one curve to another. The form of the transverse section resulting from the use of sunken groins completes this ruling action and ensures, besides a sufficient width of channel, the continuity of depths, the resistance of the bottom, the preservation and good set of the ridges.

It is therefore not sought to give the water-course the form of an artificial canal and to pursue both in the profile and cross section a uniformity of which nature sets no example; on the contrary the natural forms will be preserved which the water-course assumes under the action of the laws which control the flow of water and matter, but it will be

necessary to establish continuity by the variation of these forms. They are therefore not made to undergo any considerable modification and they are simply regulated on the model of those which are naturally good, and for accidental and perfectly unnecessary causes of irregularities troublesome to navigation resistances are substituted and suitably distributed, so that thev form permanent causes of the periodical return of the situations which are most favourable.

The banks of the stream remain sinuous and their form is made to differ as little as possible from what it has made itself, but continuity is introduced in the succession of curves. The bed continues to be formed of a succession of hollows separated by ridges, but the passage from hollows to shallows is managed by continuous gradations. The profile preserves at low water an undulating form, it remains composed of a succession of reaches with slight inclines separated by falls; but the incline of the reaches is sustained by the consolidation of the bottom and the sharpness of the falls is reduced by the satisfactory set of the ridge.

When a flood is produced it modifies the form of the bed, as would be the case on a natural water-course, the bottom is scoured in some places and is filled up in others; but these modifications are kept within the narrowest limits by the greater resistance of the bottom and the banks and the accidents which might fix their position are suppressed. As the water rises it overflows the artificial works which regulate the summer bed and spreads out without occasioning the deep disturbances which are produced in a confined bed; but as it spreads out it meets with artificial works on the convex bank, which is strengthened by them, and works on the concave bank which connect it with the submerged fore-shore. These works direct the water from stage to stage without interfering with its expansion and flow, and by their action draw the main current into the line of greatest depths and into the same position which it occupies at low water, and thus the fixed position of the *thalweg* is ensured. When the water subsides and comes back to the summer bed, it meets with a combination of circumstances which determine the return of the hollows and ridges to the places occupied by them before the flood and the reproduction of formations similar to those which existed before.

The solid matter carried down therefore continues to flow in successive stages, but the position of these is determined beforehand, gravel cannot stop in the curves where everything has been arranged to favour the preservation of the hollows and it can only be deposited in the turn from one curve to another; but here is placed a whole series of artificial works which regulate the form of the bed and the distribution of the variations in speed, which without being an obstacle to the deposit determine the form and set of it.

The depth upon the ridges after each flood varies continually and

depends upon the nature of the flood and the quantity of the matter carried down. Variable causes cannot have constant effects. But this depth is always the greatest which can result from the conditions under which the ridge has been formed and which is the effect of the nature of the river, for its maximum invariably corresponds to the satisfactory set of the ridges.

The improvement that may thus be realised has not therefore precisely the same character as that which can be obtained by canalisation by means of moveable dams, or which it is sometimes sought to obtain by the method of confinement of the bed; it is none the less considerable, for the difference which exists between the depth upon the ridges which are well or badly set is always very great. On the Rhône in particular experience has shown that in the passages where the transformation is accomplished the depth always remains sufficient to ensure easy and regular navigation.

Method of constructing the artificial works. — If the judicious choice of the form of the works is an essential condition of success, the order followed in their execution and the care taken may also exercise a considerable influence upon the result.

Every sharp obstacle, every isolated projection, provokes eddies and scour. It is therefore essential to round off the form of the works, to connect the talus of the dikes with the incline of the bottom by means of a bank, to lengthen the talus of the sunken groins by means of a covering more or less long according to their relief, to regulate their incline and widen their profile near the dike so as to effect the transition between the two classes of works, and for the same reason to reduce their incline where they join the bottom.

It is necessary to effect the modifications of the channel by degrees, by gradual and successive changes, to give the works at first but a slight relief, to construct them as far as possible in series, for their effects are completed or counteracted by each other; then after making a commencement to wait to let the stream do its work, and return to the same place later. Not only are the eddies which projecting works provoke thus avoided as well as the crumbling away which must be compensated for, but advantage is derived from the alluvial deposits which are ordinarily produced about works of small relief and rounded shape, and they are thus built up to the requisite height with appreciable economy. The effects produced can in this way be judged by degrees, foreseen conditions can be rectified if it appears necessary and the result aimed at may be obtained with more certainty.

The rules which apply to the form of the bed and the choice of artificial works are therefore to some degree applicable to their execution; and if it is essential in the form of the bed to observe continuity in the profile and in the transverse section, it is less important in the con-

struction to conform to the rule of continuity and to observe the same gradations in the successive transformations which are to lead up to the permanent form.

The success of this progressive and prudent method and the magnitude of the experiment enable us to draw from it much useful information and observations which are applicable to most river artificial works when it is a question of effecting improvements with a view to navigation or for the fixing of the banks.

The natural forces which come into play in a water-course are considerable; they sometimes acquire enormous power and the laws which regulate them are very complex. The struggle against these forces is difficult, costly and often doubtful; failure is certain if the end in view is contrary to the laws which govern them. But if instead of combating them we confine ourselves to directing them, if instead of seeking to entirely change the nature of their effects we content ourselves with guiding them by progressively modifying their action by a series of combined efforts which succeed and follow each other with continuity, success is much more certain, because the result to be attained at each point is very small and possible and the means at our disposal are better proportioned to the object in view.

§ 2. *Examples of its application.*

To complete the foregoing explanations it will be sufficient to cite a certain number of instances in which the method we have explained has been adopted. We will take examples from the whole of the river, that is to say under the most varied conditions as regards incline, discharge and the nature of the solid matter carried down. Divided in this manner they will give as exact an idea of the works already carried out on the Rhône as a complete chart of the river, and the repetition of them would only uselessly reproduce circumstances which are everywhere alike.

Concentration of water. — Traverses and inclined groins. — Secondary branches always have the inconvenience of decreasing at times of low water the discharge in the navigable branch. The closing of them at the level of low water, under the conditions which we have indicated, is understood without it being necessary to give any further explanation; it will be effected either by the aid of traverses confined to the width of the secondary branch, or by means of inclined groins, that is *traverses* which are prolonged beyond this branch to the main branch the convex shore of which they regulate. We will mention as examples the passages of Sénzan and Grigny, from kilometre 13 to kilometre 15 (Pl. IV), and the passage from Gervans-Crozes, from kilometre 86 to kilometre 89 (Pl. IX).

But besides this and without there being any question of an important

secondary branch it often happens that the channel is divided in two in the curve, one branch following the bend and the other following a chord of the curve through a depression in the shore; a deposit is formed where the two currents meet in a position that is not normal, sometimes even in the bend itself. This undesirable effect is easily suppressed by cutting up the secondary channel by a few traverses and inclined groins, which will re-establish the continuity of the shore and suppress the secondary current which is the cause of the accidental deposit. We will mention as an example the inclined groins of Jassoux in the passage of S^t Auban, kilometre 44 (Pl. VI), which rapidly removed a badly situated ridge which other artificial works were unable to touch; the *traverses* of La Perine in the passages of Oiselet and Boulangère, kilometre 230 (Pl. X); and finally the groins of La Cabane, at kilometre 322, which, three in number, were sufficient to remove in a short time a deposit formed at the foot of the quay-wall of Port St. Louis where they re-established the necessary depth (Pl. XI).

Concave bank. — Leading dams and connecting works. — As examples of leading dams regulating the form of the concave bank and of *traverses* connected with these dams we may mention:

The dikes of S^t Tous and Ivour, from kilometre 4 to kilometre 7 (Pl. III), the dike of Sénszan, at kilometre 14 (Pl. IV), the dike of Les Pêcheurs and the dike of Les Roches in the passages of Gerbay and Condrieu, from kilometre 39 to kilometre 41 (Pl. V), the S^t Auban dike, from kilometre 44 to kilometre 45 (Pl. VI); the Vions, Gervans, Lemps and Crozes dikes in the Gervans-Crozes passages, from kilometre 86 to kilometre 89 (Pl. IX), and the dikes of Le Dragonet, La Boulangère and Oiselet, from kilometre 228 to kilometre 232 (Pl. X).

The most interesting are the Les Roches, La Boulangère and S^t Auban dikes, all in very curved passages; the radius of the curve in the channel becomes 450 m. at the apex for the first two and 650 m. for the third. The S^t Auban dike which corrects a very irregular turn and is built along the bank for a considerable distance is connected with it by a group of twelve *traverses* the incline of which varies from 1.75 °/₀ to 3 °/₀.

Convex bank. — Inclined groins. — As examples of groins regulating the convex shore we may mention the inclined groins of Berne, Limony and Brèze, from kilometre 53 to kilometre 55 (Pl. VII), and the inclined groins of Lemps and S^t Estève in the Gervans-Crozes passage, from kilometre 86 to kilometre 89 (Pl. IX).

The most remarkable are those of Limony (Pl. VII) which, five in number, regulate an extensive shore with a gentle slope varying from 0.8 °/₀ to 1.5 °/₀.

Consolidation of the bottom. — Set of the ridges. — Sunken groins. — As examples of sunken groins we may mention:

The group of 20 groins at S^t Tous, laid at a depth of 3 m. to 5 m.

below the low water-level; they have been constructed to consolidate the bed and check the scour provoked by an old stone pitching protection raised 4 m. above the level of low water, and at the same time to draw the *thalweg* away from the bank against which it is always inclined to run when this bank is curved, high and smooth (Pl. III).

The group of 11 groins at Ivour, constructed for the same purpose as those of S[t] Tous and at similar depths. They have checked a general fall in the level of the water, which had begun to show signs of taking place, and rectified the change from the one curve to another the direction of which was bad (Pl. III).

The sunken groins at Les Roches which cut through the hollows and guide the *thalweg* from the bank and regulate the change in direction (Pl. V). We might also mention, as being specially intended to regulate the change in direction and the set of the ridges, the groins of Les Pêcheurs in the Gerbay passage (Pl. V); the inclined and sunken groins of Gervans, Lemps and Crozes in the Gervans-Crozes passage (Pl. IX), and finally the groins of the Bac d'Oiselet, La Boulangère and Oiselet (Pl. X).

Bottom ridges. — Finally we will mention as examples of bottom ridges, that is groins made of wood and placed right across the channel to consolidate the bed when it is liable to scour, the ridges at S[t] Auban (Pl. VI) and the ridges in the Creux des Mailles (Pl. VIII).

Concave bank without dike. — The same plate (VIII) shows, a little above the Creux des Mailles, the S[te] Rose passage; the local conditions of the curve, the incline and the resistance have allowed of the suppression of the concave dike and the simple use of connecting works ending in inclined groins. The number of passages of this kind is very limited.

§ 3. *Character of the river.*

Situation before the last artificial works were constructed.

To give an account of the results of the method we have described, it is first essential to indicate the nature of the river on which it has been adopted and the conditions it offered previously to navigation.

Character. — The course of the Rhône from its source to the sea is 750 kilometres in length of which 227 are in Swiss and 523 in French territory.

As regards its use for purposes of commerce the French Rhône may be divided into two principal sections; 1[st] the Upper Rhône, from the Swiss frontier to Lyons, which may be regarded as a waterway of purely local interest serving for the transport of large quantities of building materials along its banks; its length is 193 kilometres; 2[nd] the Lower

Rhône and the Maritime Rhône, between the confluence with the Saône at Lyons and the sea, which, connected by the Saône with the navigable ways of the Centre, the North and the East, form part of the system of principal waterways and seem called upon to exercise a decisive influence upon the commercial movement of many of them.

The works for the confinement of the bed have been constructed at various times in these two sections. The Miribel canal which we have mentioned belongs to the first. The works constructed after the method we next described belong to the second section, the only one which by reason of its commercial importance could justify the expense of a combined operation. We will therefore only occupy ourselves in the latter portion of this Report with the second section of the river.

The length of the Rhône between Lyons and the sea is 330 km., between Lyons and the lock of the sea-water canel of St Louis 324 km. The height of the confluence of the Saône and the Rhône is 158.58 m.; it results that the average incline is 0.48 m. per kilometre $\left(\frac{1}{2080}\right)$.

This incline is very unequally distributed and presents the following principal variations:

from Lyons to the Isère for	108.50 km.	Average incline . 0.50 m.	$\left(\frac{1}{2000}\right)$
" the Isère to the Ardèche .	87.00 km.	" " . 0.775 m.	$\left(\frac{1}{1304}\right)$
" the Ardèche to the Durance	57.00 km.	" " . 0.513 m.	$\left(\frac{1}{1949}\right)$
" the Durance to Soujean .	28.00 km.	" " . 0.260 m.	$\left(\frac{1}{3846}\right)$
" Soujean to St Louis . .	47.00 km.	" " . 0.023 m.	$\left(\frac{1}{43\,478}\right)$

At certain points the incline is greater than the average and passages are met with in which for a short distance it even becomes more than 3 or 4 m. per kilometre.

The superficial velocity of the current varies greatly in the same section; the variations in velocity met with within the limits of the navigable waters are included in the following:

at low water-level from 1.00 m. to 2.50 m. per second at varions points;
at mean water-level from 1.60 m. to 3.50 m.;
at high water-level from 2.50 m. to 4.00 m.

But at mean and high water the channel is very wide, the velocity varies greatly from point to point and boats going up stream can avoid the swiftest parts of the current.

In time of high floods when navigation is interrupted a velocity of 5 or 6 m. has been registered.

The bed of the Rhône consists of a very thick layer of gravel which is very unstable and easily washed away. In certain places rocky points emerge, in a few others cross bars of rock stretch from one bank to

the other. This formation of the bed is almost the same over the whole river and the only difference from one point to another is in the size of the gravel. From Soujean to 28 km. below the Durance, the last confluence, gravel disappears and only fine sand is found.

The discharge of the Rhône is very variable; the difference between the volume in time of low water and floods is enormous, as appears from the following table:

	Minimum observed in 1884.	Conventional low water in 1878.	Maximum observed in 1856.
Above the confluence with the Saône. .	130 cub.m.	140 cub.m.	5,400 cub.m.
Below " " " " "	150	240	7,000
" " " " " Isère . .	250	365	9,700
" " " " " Ardèche.	300	380	11,900
" " " " " Durance.	370	450	13,900

Moreover the discharge during the flood of 1856 is certainly less than the possible maximum, because on the one hand the floods of several tributaries were considerably less than their known maximum, and on the other hand the maxima of the different streams did not coincide.

However, these extremes are very rare and in order to judge of the character of the river with respect to its navigability it is less necessary to regard exceptional circumstances than such as those the repetition of which is sufficiently frequent to influence trade.

The floods on the Rhône rise suddenly and rapidly subside; they nearly everywhere cover considerable areas and easily managed currents are met with, in fact navigation is not suspended until 4 m. above low water-level is reached, when the passage through bridges becomes dangerous. Interruptions on account of floods are always of short duration.

Low water, the duration of which is generally much greater, is a much more serious obstacle, because the inconvenience it causes lasts longer and because in spite of the decrease of the discharge it presents in certain places of little depth, that is to say in most unfavourable conditions, almost as great a velocity as at high water. It is then that the profile of the water consists of a series of falls and the local inclines differ most from the average. The increase of depth therefore in time of low water has the double effect of lengthening the periods during which navigation is pos-

sible and of diminishing the efforts necessary for making head against the current in these periods.

To define the depth of a river it is customary to give the depth above a certain low water mark which is taken as a standard; generally it is the level of ordinary low water. On the Rhône the level has been adopted which was observed when the regulation works were commenced.

The low water discharge of the Rhône in the most difficult part, where the most pronounced inclines between the Isère and the Ardèche are met with, is almost entirely supplied by the upper Rhône, the Saône and the Isère. The upper Rhône and the Isère, fed by glaciers, have their minimum in winter; the Saône, fed by rains, has its minimum in summer. The conventional low water of the Rhône occurs when the upper Rhône and the Isère are both at their minimum and when at the same time the Saône is at its lowest winter level. For the Rhône to reach a lower level than this, a long and cold winter, the condition of the minimum of the upper Rhône and the Isère, must succeed a prolonged drought without autumn rains, the condition of the minimum of the Saône. This circumstance occurred in 1884, a year when the supply of water in canals presented serious difficulties; it had not been observed before, so that the low water mark adopted on the Rhône as a standard of comparison may be considered to correspond to the state of water which, without being the lowest possible, is exceptional and rare.

All the information give hereafter refers to this low water-level which has been chosen considerably lower than on most rivers. It is essential that this should be known that the importance of the results obtained may be fully appreciated.

The above remarks suffice to show that, as regards the mobility of the bed, the velocity of the current and the irregularity of the discharge, the Rhône offers a more unfavourable combination of conditions than any other large navigable river. And these remarks at the same time reveal the extent of the difficulties in the way of shipping which it has been necessary to remove to improve the navigable condition of the river.

The principal difficulties met with by boats were the bad direction of the channel, the violence of the falls over the shallows, the insufficient depth and the prolonged and frequently unlooked-for stoppages which were the necessary consequence.

The irregularity of the channel and the sharp turns of the *thalweg* did not admit of boats being steered simply by the helm; ropes had to be used in these passages to keep the boat in the right direction, and this method was dangerous and tedious, and as it had to be resorted to a great many times in one journey it considerably increased the expense and caused much delay.

The fall of some rapids at low water was such that boats fitted with

1000 or 1200 horse-power were unable to pass them without being hauled up.

The depth at low water-level became 0.40 m. and even less in some passages; the length of time during which the river was navigable was short, stoppages were produced every year and often lasted 90 or 100 days and sometimes more.

The extreme instability of the bed occasioned at each flood considerable changes in the channel and the transport of enormous quantities of gravel, causing the sudden formation of shoals capable of stopping navigation even at comparatively high water.

In many places dangerous reefs were to be feared. Moreover a certain number of bridges constructed at too low a level stopped navigation considerably before the speed of the current demanded, and thus deprived it of a fairly long period when the river was available for fully laden transports.

In spite of this combination of unfavourable circumstances the Rhône, upon which a considerable fleet of fast and powerful boots had been established besides those which simply floated down with the current, served an extensive commercial movement and continued to be the best way of communication, both as regards rapidity and the low price of transport, until the opening of railroads.

During this period of activity however very few regulation works were undertaken and excepting a few tow-paths the greater part of the works constructed before 1860 are of another order and were generally intended for protection against inundations.

But with the opening of the railway from Lyons to Avignon the situation changed completely. Finding in the railroad a more rapid and essentially more regular means of communication, commerce would no longer put up with the frequently unlooked-for and prolonged interruptions it had up to that time submitted to and it gradually forsook navigation. The shipping trade then vociferously demanded the improvement of the river. Several projects were studied, but the resources swallowed up every year in this sort of work did not admit of the execution of the plans. From 1860 to 1878 only the worst passages were attempted, according as the needs for their improvement were most pressing and the extent of the funds available would allow. A series of corrections was thus undertaken which were similar in idea to the Miribel canal on the Upper Rhône, which we have already discribed, but on a considerably smaller scale. The results obtained were very various; certain local improvements were effected, but without the results being of any real service to commerce, either because in many places the improvements realised were compensated by aggravations up and down stream, or because even without this inconvenience local improvements were unable to modify in any effective manner the conditions favourable to navigation,

the progress of which remains uncertain as long as there are bad passages and is always regulated by the worst of them.

These works had moreover shown many errors in the system employed; they had demonstrated the importance of a good form of bed, the inconvenience of long straight stretches, the necessity of maintaining numerous changes in direction and of ensuring continuity in the curve of the banks, and the desirability of lowering the level of the dikes.

With these successive improvements it seemed that the good results obtained in certain places would easily be generalised and that it was especially necessary to continue the works upon this method throughout the whole length of the river at once, in order to ensure for the whole distance a really effective improvement for purposes of commerce.

This idea gave rise to the last project of improvement. This project was adopted by the law of 13th May 1878 which laid aside the sum of 45 millions for its execution.

Work was immediately begun and rapidly pushed on with, but the more it progressed the more evident the errors in the system adopted became; it was clear that the inconveniences observed were not only due to the lack of solidarity, but also to the principle itself upon which the method was based, and the fact had to be recognised that by a system of regulation based upon the confinement of the bed with low leading dams which should fix the normal profile, complete success would not be obtained and only a partial and insufficient improvement would be realised.

This conduced to the employment of cross works, concurrently with the leading dams, and to the completion and modification by means of sunken works of the action of works rising above the water; their effect would be better noted and advantage would be derived from them. These works however were not new; they had frequently been proposed and employed in France and abroad; but the use made of them on the Rhône, under the conditions that we have indicated, constitutes a method that is new in most respects, not only as regards the employment and combination of the different types for obtaining combined effects, but also, as appears from the account we have given, from the principles themselves upon which they are based and from the difference in the end it is sought to attain.

The first trials on this new method were in 1882; they were continued for two years; the success obtained and the experience acquired have established opinions and allowed of the formulating of the very simple rules which we have stated and which since 1884 have been applied to new works, while at the same time the type of the old works was followed as nearly as possible.

§ 4. *Results obtained.*

Although the regulation works upon the Rhône, undertaken upon the passing of the law of 13th May 1878, are not entirely finished and although their construction must continue for several years longer, the bulk of the work is complete; what remains to be done is inconsiderable and the expense of it does not amount to much; these works will be more especially for the consolidation of the results obtained; the limit of possible progress is now almost reached and the conditions of navigability, at present very satisfactory, are hardly susceptible of further modification.

Having got so far it is therefore possible to judge of the importance of the progress effected and to define the new conditions shipping encounters today upon the Rhône.

This progress is seen in the increase in the minimum depth, the reduction of the number of bad passages and consequently the extension of the periods favourable to navigation, and the reduction of stoppages.

Increase of minimum depth at low water. — The minimum depth before the regulation often fell below 0.40 m. in a certain number of passages (it has even descended to 0.35 m. and 0.30 m.). This depth has increased progressively and the observations taken at low water since 1878 enable us to quote the following figures for the minimum:

At	low	water	in	1878	the	depth	was	0.40 m.
"	"	"	"	1882	"	"	"	0.80 "
"	"	"	"	1884	"	"	"	0.90 "
"	"	"	"	1887	"	"	"	1.05 "
"	"	"	"	1893	"	"	"	1.25 "

This minimum of 1.25 m. may be counted upon today; it only exists in one passage which is in the course of transformation. Therefore 0.85 m. has been gained upon the condition before the regulation works were commenced; the minimum depth has become more than three times what it was. The actual gain for shipping is still more considerable, because the direction of the channel is better, the transition from one curve to another is less abrupt, from which it results that boats are more easily able to follow the line of greatest depth and make use of the deepest channel available.

Reduction of the number of bad passages. — The number of bad passages in which there is at no time a depth sufficient for boats when fully laden has been decreasing every year.

The depth available on each ridge is determined by soundings which are taken every week in time of low water and every fortnight when the water is at an average height. All the soundings relating to one shallow are expressed by a curve drawn after a scale by which the position of the low water mark is determined. The examination of the

curve therefore enables us at any given moment to find what the depth would be in the shallow if the water reached the low water-level, and consequently to determine by means of the plan of comparison the position of shallows throughout the whole length of the river.

The following table summarises this situation for a few years since the commencement of the works; these years have been chosen from those which have given the lowest water-levels and during which it was possible to check the depth at low water from direct observation.

The results are given, first for each of the districts into which the Rhône is divided, and afterwards grouped together for the whole river.

Diagrams annexed to this Report reproduce in a striking manner the same indications for three years: for 1878 at the commencement of the works, for 1884 a year of exceptionally low water, and for last year, 1893 (Pl. XII, XIII, XIV). Low water-level has been represented in these diagrams by a horizontal line and depths of 1.00 m., 1.20 m., 1.40 m. and 1.60 m. are marked below. The existing shallows are marked in their kilometric position and at their depth below low water.

These diagrams as well as the table are most instructive; the improvement effected is shown in them most clearly, as a few examples will suffice to prove.

The passages which presented less than 1.20 m. at low water were 81 m. in number before the regulation was effected; only 10 remained in 1884, 3 in 1887 and none today.

The passages which were less than 1.40 m. in depth were 104 m. in number before the regulation; 31 remained in 1884, 16 in 1887 and only 3 today.

But this examination not only shows that the progress has been considerable, but also that this progress is regular and constant and becomes more pronounced year by year, a fact which is not less important since it points to the favourable duration of the results obtained.

It may therefore be very reasonably supposed that in course of time and with the help of a few improvements the minimum low water-level will be raised to about 1.40 m. or 1.50 m. The detailed study of the regulated passages would perhaps lead to more sanguine expectations; it seems however of little use to go into the matter as the conclusions would be too uncertain. In work of such an entirely novel character, to which experience everyday reveals more certain facts and by degrees supplies data to a science that is still imperfect, it seems prudent to pass over doubtful eventualities and to regard only the realities before us.

Lyons to St Vallier.				From St Vallier to the Ardèche.					From the Ardèche to the sea.					From Lyons to the sea.				
ber of passages.				Number of passages.					Number of passages.					Number of passages.				
1882.	1884.	1887.		1878.	1882.	1884.	1887.		1878.	1882.	1884.	1887.		1878.	1882.	1884.	1887.	
—	—	—	—	2	—	—	—	—	3	—	—	—	—	5	—	—	—	—
—	—	—	—	4	—	—	—	—	3	—	—	—	—	8	—	—	—	—
—	—	—	—	9	—	—	—	—	5	—	—	—	—	19	—	—	—	—
—	—	—	—	9	—	—	—	—	8	—	—	—	—	22	—	—	—	—
2	—	—	—	14	2	1	—	—	9	—	—	—	—	30	4	1	—	—
2	1	—	—	17	3	4	—	—	11	2	—	—	—	40	7	5	—	—
4	3	2	—	27	6	5	—	—	14	2	—	—	—	63	12	8	2	—
6	4	2	—	34	10	6	1	—	16	2	—	—	—	81	18	10	3	—
10	5	2	—	38	11	9	5	1	20	4	2	—	—	91	25	16	7	1
18	14	7	1	42	19	14	9	2	22	5	3	—	—	104	42	31	16	3
28	21	16	1	45	27	25	20	5	28	5	5	2	—	111	55	51	38	6

These results correspond nowadays to a very satisfactory state of navigability, but which the above figures however much information they may give do not alone suffice to make perfectly evident. It is easy to show in a still clearer manner the importance of the improvement effected and the advantages it ensures for navigation.

Lengthening of periods favourable to navigation. — On a canal or canalised river the depth is almost constant; it is one of the essential conditions of navigability on the waterway under consideration; but on a river of a variable nature and free course like the Rhône, the depth is variable, and its minimum at low water gauges these same conditions of navigability the more imperfectly as the low water-level with which this depth is compared represents a more exceptional and unusual state of water and as this minimum is consequently also exceptional and unusual.

To have a suitable means of comparison with other navigable ways, it is necessary to translate these data and extract the duration of periods favourable to navigation, or better still the average duration corresponding to the various depths according to the supposed or already realised minimum of low water.

This result may be obtained in the following manner:

By studying the nature of the shoals it is found that when the water rises the depth rarely increases in proportion to the variation registered by the neighbouring scale, and it becomes apparent that under the most unfavourable conditions a rise of 0.25 m. only corresponds to an increase of 0.20 m. on the shoal.

On the other hand by comparing the movement of the water with the principal scales on the Rhône a calculation has been made of the number of days during which the water keeps at a height varying from one 0.25 m. to another. This list has been made for a period of twenty years, from 1871—1890, and the condition of the water during an average year has been deduced. This condition varies from one section of the river to another, the water falling more or less rapidly or with greater frequency in each of them according to the character of the tributaries which feed it. The section presenting the most unfavourable conditions has been chosen, a section in which low water occurs most frequently and lasts longest.

The figures indicating the number of days during which the water remains at a height varying from one 0.25 m. to another above low water-level, evidently, from what has been said above, give the number of days during which the depth varies from one 0.20 m. to another above the minimum at low water-level.

The results of these calculations are collected together in the following tables which give, under slightly different forms, the conditions af navigability corresponding to the minimum depths at low water which vary from 0.40 m. to 1.60 m.

Number of days corresponding to the variations in depth within the following limits:

DEPTH:	The minimum at low water being						
	0.40 m. Situation in 1878.	0.80 m. Situation in 1882.	0.90 m. Situation in 1884.	1.05 m. Situation in 1887.	1.25 m. Situation in 1893.	1.40 m. Probable situation	1.60 m.
	Days.	Days.	Days.	Days.	Days.	Days.	Days
below the minimum	2	2	2	2	2	2	2
between 0.40 m. and 0.60 m.	9						
„ 0.60 „ „ 0.80 „	18						
„ 0.80 „ „ 1.00 „	26	9	4				
„ 1.00 „ „ 1.20 „	37	18	13	6			
„ 1.20 „ „ 1.40 „	46	26	22	16	6		
„ 1.40 „ „ 1.60 „	45	37	33	24	16	9	
„ 1.60 „ „ 1.80 „	43	46	41	35	24	18	9
„ 1.80 „ „ 2.00 „	38	45	44	42	35	26	18
above 2.00 „	101	182	206	240	282	310	336
	365	365	365	365	365	365	365

In this first form we have for each stage the number of days corresponding to the variations in depth within the given limits. It may be seen that as a rule the water remains for two days in the year below the low water-level (that is for 40 days during the period of twenty years which have been taken to arrive at the average); it may fall to about 0.25 m. below and consequently during these two days leave only a depth of less than 0.20 m. for the corresponding minimum.

The same results may be given in a still more practical form by showing the number of days during which the depth is above a certain limit, that is the number of days during which, given a minimum low water-level, boats may be loaded to such and such a degree. The second table shows this.

Number of days corresponding to a depth above the following limits:

DEPTH:	The minimum at low water being.						
	0.40 m. Situation in 1878.	0.80 m. Situation in 1882.	0.90 m. Situation in 1884.	1.05 m. Situation in 1887.	1.25 m. situation in 1893.	1.40 m. Probable situation	1.60 m.
	Days	Days	Days	Days	Days	Days	Days
Above 0.40 m.	363						
„ 0.60 „	354						
„ 0.80 „	336	363	363				
„ 1.00 „	310	354	359	363			
„ 1.20 „	273	336	346	357	363		
„ 1.40 „	227	310	324	341	357	363	
„ 1.60 „	182	273	291	317	341	354	363
„ 1.80 „	139	227	250	282	317	336	354
„ 2.00 „	101	182	206	240	282	310	336

These figures facilitate the comparison between the successively different conditions through which the improvements have passed and those that it may be hoped will be obtained. We will confine ourselves to comparing the condition before the work began and the present time by bringing together the corresponding figures in another table which will show the gain realised for each depth from the minimum 0.40 m. up to 2.00 m.

	Number of days in an average year corresponding to greater depths than indicated by the figures below.								
	0.40 m.	0.60 m.	0.80 m.	1.00 m.	1.20 m.	1.40 m.	1.60 m.	1.80 m.	2.00 m.
Present condition (1893) . .	365	365	365	365	363	357	342	317	282
Before the improvements . .	363	354	336	310	273	227	182	139	101
Difference.	2	11	29	55	90	130	160	178	181

Thus before the improvements the minimum depth at low water fell to 0.40 m.; there was a depth of more than 1.60 m. during 182 days and more than 200 m. during 101 days.

Now that the minimum depth at low water is 1.25 m., there is more than 1.60 m. for 342 days and more than 2.00 m. for 282 days; 160 days have been gained for the first depth and 181 days, *six months*, for the second.

If a minimum of 1.40 m. is arrived at, as observation seems to indicate we may depend upon, there will be a depth of more than 1.60 m. during 354 days and of more than 2.00 m. during 310 days; the duration of this last depth will be more than trebled.

This comparison, besides its principal result, namely the demonstration of the improvement effected, confirms the observation made above and shows how far the expression of the minimum depth is always insufficient to characterise the navigable conditions of a river with an open course. Taken in an absolute sense it shows between a state in the river which gives 1.60 m. at low water and that which gives only 1.25 a difference which as regards commercial utility appears at first sight enormous; in reality the question is reduced to this: in the first case there will be more than 1.60 m. for 363 days, and in the second case there will be more than 1.60 m. for 341 days. The difference only comes to 22 days during which the depth remains between 1.25 m. and 1.60 m., and is not less than 1.40 m. for more than 6 days.

Thus the observation we made at the commencement of this paragraph is confirmed; the actual minimum depth at low water will continue to increase; real advantages for navigation and greater safety for goods will certainly be the result; but the combination of conditions favourable to navigation cannot be further modified to any great extent, because their transformation is almost entirely accomplished and the margin of possible progress is very much reduced.

Reduction of stoppages at low water. — The lengthening of the periods of easy navigation corresponds to a reduction of the duration of stoppages. It is useful in this manner to show the progress made; in fact the stoppages have the effect of reducing the cargoes and they especially influence commercial movements, because by decreasing the utility of the plant they increase the cost of transport; but when they last a very long time and occur in a more or less unlooked-for manner, as was the case upon the Rhône, they exercise a still more pernicious influence, rendering it impossible to maintain regularity, a condition not less essential than a good market for a large transport trade.

Stoppages in consequence of low water have almost ceased to occur and the progressive manner in which the commencement of them has been retarded demonstrates the extent of the progress.

The following table gives for each year the height above low water-level at which navigation became impossible.

In 1874 this height was	. . . .	0.80 m.
" 1877 " " "	. . . .	0.78 "
" 1878 " " "	. . . .	0.73 "
" 1879 " " "	. . . .	0.67 "
" 1880 " " "	. . . .	0.60 "
" 1881 " " "	. . . .	0.53 "
" 1882 " " "	. . . .	0.35 "

In 1883 navigation was not interrupted and in 1884 it was only stopped when the water reached low water-level. In 1884 the water was quite exceptionally low and for the first time since observations have been taken on the Rhône it went below the low water-level. Navigation was able to continue until this extremely low level was reached; therefore the depth in 1884 at this low water-level was 0.90 m., whereas in 1874 it was 0.40 m. With this minimum of 0.40 m. below low water-level, when the water was 0.80 m. above this level the depth became 1.05 m. and boats which could still navigate with advantage when drawing 0.85 m. were obliged to stop; whereas in 1884 with a depth of 0.90 m. on one ridge and 0.95 m. on others they were still able to pass. The gain for navigation therefore has been more considerable than is indicated by the increase in depth, and while the depth on the ridges increased only 0.50 m. the level of the water which stopped navigation was reduced by 0.80 m. This is due, as has been said above, to the fact that the direction of the channel is easier to follow over the more submerged ridges and consequently the available depth can be better utilised.

Since the winter of 1884—85 stoppages at low water have almost ceased to occur, and during the last nine years there has only been one stoppage due to this cause which has lasted for eight consecutive days. It must also be remarked that although this stoppage was occasioned by the extremely low level of the water, the main cause of it was not due to the decrease in depth; navigation was not completely interrupted during these eight days and some boats continued on their course; but this stoppage occurred with the first frosts of the winter of 1890–91 and it was caused more particularly by the severe cold which froze the ropes and rendered navigation very difficult and trying; it was moreover of little importance as the other navigable ways were closed and the ports of Lyons could not be approached.

During the period from 1871—77, before the regulation was effected, there were stoppages for 479 days, or an average of 71 a year, for 111 days in 1871, 102 in 1872, 145 in 1874.

During the first period in which regulation was attempted, from 1878 to the end of 1884, there were stoppages for 171 days, or an average of 24 days a year. If navigation had had to cease with 0.80 m. above low water, as was the case before the regulation, there would have been stoppages for 375 days, or an average of 55 a year. In 1884 when the

water was exceptionally low there were stoppages for 44 days; there would have been stoppages for 145 days under the conditions existing in 1874.

Since the end of 1884 the total for stoppages has been 23 days, which gives an average of 3 days a year; there would been have 76 if navigation had had to cease at 0.80 m. above low water-level; and there would have been stoppages for 112 days in 1890 and for 107 in 1891, or 219 days for these two years, during which in reality the last interruption to navigation only lasted 8 days.

On an average for 66 days the water is less than 0.80 m. above low water; this is therefore the average length of time stoppages would last if an improvement in the river had not been effected. Under the present state of things however, with a minimum depth of 1.25 m. at low water, a considerably lower level than this would be necessary to arrest navigation. But the water only remains below this level for 2 days in the year, therefore the possible length of time for stoppages to last is reduced to a maximum of 2 days in the year instead of 66. It may be said without exaggeration that stoppages at time of low water, which were formerly a serious matter, practically no longer occur.

Suppression of other hindrances to navigation. — But the improvement does not simply consist in the increase of the depth, the suppression of stoppages at times of low water, and the lengthening of the periods favourable to navigation; other less important but still considerable results have been obtained. The channel has been regulated, the transition from one curve to another has been rendered less abrupt in proportion as the depth upon the shallows increased; the manoeuvres of boats have been simplified and steering has been made easier, while the falls have been lengthened out, the rapids reduced, and the draught of boats has continually increased.

Moreover the greater part of the dangerous reefs have been cut down and the bridges that were too low have been raised, so that navigation has not only been possible for a greater length of time during low water, but it has also been considerably extended during high water.

The only obstacles which have not been reduced are those upon which regulation works can have no effect — fogs and winds which never cause long interruptions but merely delays, high floods which quickly subside and ice which only appears upon the Rhône later and lasts less time than upon other navigable ways.

Comparative summary of the combination of conditions favourable to navigation before and after the construction of the works. — As a conclusion to this investigation it will be well to summarise the combination of circumstances which determine the navigability of a river and thus to compare the present with the former condition of the Rhône. This is effected in the following table.

In this table the year has been divided into three periods:

1. That in which navigation is impossible on account of floods, low water, ice, winds or fogs. This period which consisted of 93 days is reduced to 14.

2. That in which navigation is possible but difficult and tedious on account of the complication of manoeuvres and the reduction of cargoes. This period which consisted of 129 days is reduced to 14 and other improvements besides the increased depth have singularly lessened the difficulties.

3. The period in which navigation was easy for boats when fully laden, which used to last for 145 days, is now increased to 337 days.

Comparative table of the combination of conditions favourable to navigation in an average year.

		Before the regulation.		Present condition.		Gain.
		Days.		Days.		Days.
Navigation interrupted by	Ice.	6	93	6	14	77
	Fog and wind.	2		2		
	Low water.	66		2		
	Floods more than 4.50 m. above low water-level.	4		4		
	Lowness of the bridges.	15		—		
Navigation rendered difficult	on account of necessary reduction of cargo and the difficulty of steering and manoeuvring.	129		14		115
Navigation rendered difficult	for boats when fully laden, steering being easy and the currents manageable.	143		337		192
		365		365		

Formerly the state of the Rhône could be very simply defined:

Navigation was stopped for three months, was difficult for four and easy for five.

Today however we can count upon:

Fourteen days during which navigation is interrupted, fourteen during

which it is difficult, though not so much so as formerly, and eleven months during which it is easy for vessels when fully laden.

There are probably few navigable ways on which the combination of conditions is better; the only difficulty which still exists is the velocity of the current, which cannot be modified more than has been done by the toning down of the falls; it is certainly considerable, but it only tells upon one of the items among the expenses of transport, viz. the traction, and it is every day reduced by the progress made in mechanical arrangements. Moreover the great speed of the Rhône is due to its incline and the shortness of its course, and if the boats which have to overcome these difficulties cannot hope to make their tariffs as low as on navigable ways without a rapid current, they at least find a partial compensation for this inconvenience in the fact that they have not to traverse the great distances which many waterways present.

The enormous change upon the Rhône in the conditions favourable to navigation has allowed of steamboats utilising their full capacity and doubling their tonnage without increasing their dimensions. The number of vessels, formerly excessive, is now insufficient to satisfy the growing needs of commerce and the necessity of increasing it has become most pressing.

Two causes have prevented this from being done already; one was the timidity felt by capitalists unaccustomed to enterprises of this nature on account of the falling off of navigation after the opening of railroads and the difficulties met with before the regulation was effected; the other was the uncertainty prevailing with regard to the importance and duration of the improvements which might result from these works and consequently with regard to the manner in which boats should be built for a profit to be realised. These two causes have disappeared. The improvement realised has allowed of freights being reduced and of the establishment of regularity such as never existed before, and these two results have brought back the trade to the river and with it the confidence of the public; moreover the evidence, magnitude and excellence of the results have become certain and the new conditions of the river are today well defined and well known. The boats have also undergone considerable transformation and their size has been increased, a large number of new ones are in course of construction and we might with little risk of mistake assign an almost certain date in the near future to a large development of the commercial movement.

Indirect advantages resulting from the works. — Besides the improvements realised with respect to navigation, the works upon the Rhône have resulted in advantages of another kind which are calculated in course of time to indirectly produce a notable increase in the public wealth.

That part of the Rhône which has not been regulated is divided up

into a number of branches and spreads over a considerable area. A glance at the chart of the river which has existed for rather more than twenty years shows false branches in every direction and often one or several positions abandoned by the main channel. In many places the surface occupied by these branches is several kilometres wide and when the Rhône moves to one side or the other it destroys everything if meets with and leaves behind it stretches of sand and gravel that are of no value or utility.

On the lower Rhône, below Lyons, the danger of the banks being undermined and washed away has for a long time been contended with and the area given up to the capricious movements of the river has been considerably reduced. When the works were commenced this area was still considerable and as regards the danger it entailed could be divided into two parts, in one of which, the furthest from the stream, the land was cultivated but had a depreciated value on account of the risk of the crops being carried away; the other part, in the immediate neighbourhood of the stream, consisted of land which yielded practically nothing and the possession of which was in the last degree precarious.

This state of things has already been considerably modified wherever the regulation works have been completed, the banks are fixed and the property which was exposed to the danger of disappearing no longer has anything to fear. Moreover accretion is produced behind the works, alluvial soil is formed and vegetation commences; in some places the modification has been fairly rapid and the number of farmers anxious to rent this recently formed land continually increases. These holdings are becoming more and more numerous and it is of the highest importance to encourage their occupation. By these means, that is to say by renting for short periods the recent alluvial deposits which are still covered at mean water-level, the State finds itself in a position to direct the formation of these deposits so that they may not be provoked by works which might be prejudicial to the general interests of the valley, which would certainly be the case if they remained the property of persons dwelling on the river banks.

Although the fixing of the banks improves the property while it ensures its preservation, if must be remembered that it has been effected with the object of bringing together the low waters into a summer bed which is naturally narrow and quite inadequate in time of floods. And if the alluvial deposits which form behind the works were not kept at a sufficiently low level to allow of the expansion of the high waters and floods, the height and violence of these latter would rapidly increase and would endanger both the preservation of the works and even the safety of the property which their presence had brought into existence.

The lands reclaimed from the river should therefore be kept at a low enough level for them to be inundated by the highest floods. This however

need not prevent them from acquiring a considerable value. Formed between the works that slope towards the river they naturally assume a similar incline and when the water covers them it will merely pass over them and flow away again leaving behind the fertilising elements it has brought down, which will go a long way towards compensating any damage that may have been occasioned. Such has been the result upon the Rhône. In the upper part of its course there have for several centuries existed dikes which were constructed as a protection against inundations; between these dikes alluvial deposits have been formed which are often inundated and which nevertheless in some cases have become more valuable than lands in the immediate neighbourhood which are beyond the reach of the floods.

What will the twofold increase in value amount to resulting on the one hand from the security to property throughout a widely extended area, and on the other hand from the absolute creation of new lands of perhaps equal dimensions? It is difficult to foresee and it will always be difficult to calculate; the first it will always be difficult to estimate and the second will always be represented by the whole value of the newly formed lands. And if it is remembered that the area which benefits from these works in either one way or the other stretches over a distance of more than 300 km. and amounts to several thousand hectares, it will be apparent that the total increase in value is considerable and more or less equivalent to the amount expended on the works.

§ 5. *Cost.*

The cost provided against by the law of 13th May 1878 was 45 millions, which covered besides the regulation works a certain number of undertakings which were not directly connected with the improvement of the channel. The expenses actually incurred for the combination of works of the first project amounted to fr. 39,500,000. We may therefore be certain that they will be completed within the prescribed limits.

If from the total cost we deduct that of the works which have no connection with the regulation properly so called, the cost of the latter actually amounts to fr. 36,900,000, or for the 324 km. in question a cost of fr. 114,000 per kilometre, and this may when the work is complete amount to fr. 120,000 or fr. 125,000.

This cost, which is less than any other system of regulation would have entailed, would have been less still if we had from the commencement had a knowledge of the methods which have been gradually developed from the experience acquired in the earlier stages of the work and the observations of all the engineers who took part in the management.

It must in fact be remarked that until 1882 the only system adopted

was that of leading dams to fix the normal profile and the very elaborate forms given to these frequently involved tedious and costly work. The first attempts upon another method were only made for the first time in 1882, and it is only since 1884 that the experience acquired has allowed of the definite adoption of the system that we have described and which, while it effects less change in the natural form, is more easy of execution and is less expensive.

The comparison of the expenses during these two periods and of the results they have given respectively completely established the fact that the second method is the most economical.

The diagrams of the position of the shoals before 1878 and in 1884 show the progress made during this first period; the corresponding cost of the work was in round numbers fr. 32,500,000.

The comparison of the diagrams for 1884 and 1893 shows the progress made during the second period; the cost of the regulation works amounted to fr. 4,400,000.

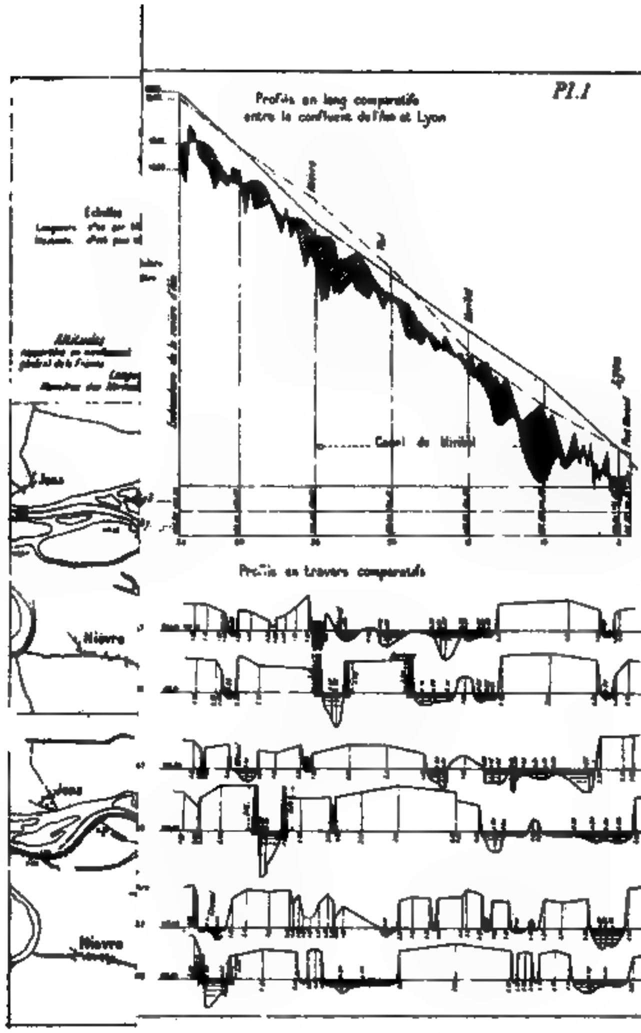
The saving due to the change of system is certainly less than the difference between these amounts, for many works of the first period have contributed to the progress made; but at the same time many of them had to undergo great alterations and a good many had to be demolished, especially the dikes on the convex banks, most of which were pulled down.

However without stating a definite sum it clearly results from this comparison that the difference in cost between the two methods is considerable and it is certain that we shall find in the one which complies most with the laws which regulate the flow of rivers of unstable bottom, not only greater chances of success and a greater possibility of effecting a more complete improvement, but also an economical advantage. After the great experiment that we have given some account of we are firmly convinced that works of this nature, whether it is a question of facilitating navigation or of simply fixing the banks for the protection of property, only require a little observation and intelligence and much patience, and should entail only a moderate expenditure.

Inscriptions des Planches.	Inschriften der Zeichnungen.	Description of the Plates.
PLANCHES I & II.	BLATT I u. II.	PLATES I AND II.
Regularisation entre	Regulirung zwischen	Regulation between . . . .
Profils comparatifs dans l'étendue du canal.	Vergleichende Profile in der Kanallänge.	Comparative sections in the length of the canal.
Fond du lit.	Sohle.	Bottom of the bed.
Altitudes rapportées au nivellement général de la France.	Wasserstände, bezogen auf die allgemeine Nivellirung in Frankreich.	Altitudes brought to the general levelling of France.
Plan de la plaine de Miribel avant l'exécution du canal.	Plan der Ebene von Miribel vor Ausführung des Kanales.	Projection of the plain of Miribel before the making of the canal.
Plan actuel du Canal de Miribel.	Plan des nunmehrigen Kanales von Miribel.	Projection of the Miribel Canal.
Profil en long comparatif entre le confluent de l'Ain et Lyon.	Vergleichendes Längsprofil zwischen dem Einfluss des Ain und Lyon.	Comparative longitudinal section between the confluence of the Ain and Lyon.
Passage.	„Pass".	Passage.
PLANCHES III & IV.	BLATT III u. IV.	PLATES III AND IV.
Epis plongeants. „ noyés.	Untergetauchte Buhnen.	Submerged groins.
Atterrissement.	Anschwemmung.	Alluvial deposit.
PLANCHES V & VI.	BLATT V u. VI.	PLATES V AND VI.
Digue de halage.	Leinpfaddamm.	Towing dike.
Carrière.	Steinbruch.	Quarry.
Eglise.	Kirche.	Church.
(Pour les autres inscriptions, voir les traductions „Planches I—VI".)	(Die übrigen Inschriften siehe unter Uebersetzungen zu Blatt I—VI.)	(For other references, see translations under Plates I—VI.)
PLANCHES VII & VIII.	BLATT VII u. VIII.	PLATES VII AND VIII.
Graviers.	Grand.	Gravel.
Ruisseau.	Bach.	Stream.
Moulin.	Mühle.	Mill.
Route nationale.	Landstrasse.	High road.
Seuils de fond.	Bodenerhebungen (Untiefen).	Ridges in the bottom.
(Pour les autres inscriptions, voir les traductions „Planches I—VI").	(Die übrigen Inschriften siehe unter Uebersetzungen zu Blatt I—VI.)	(For other references see translations under Plates I—VI).
PLANCHES IX—XII.	BLATT IX—XII.	PLATES IX—XII.
Château.	Schloss.	Castle.
(Pour les autres iuscriptions, voir les traductions „Planches I—VII".)	(Die übrigen Inschriften sind unter den Uebersetzungen zu Blatt I—VIII zu finden.)	(For other references, see translations under plates I—VIII).

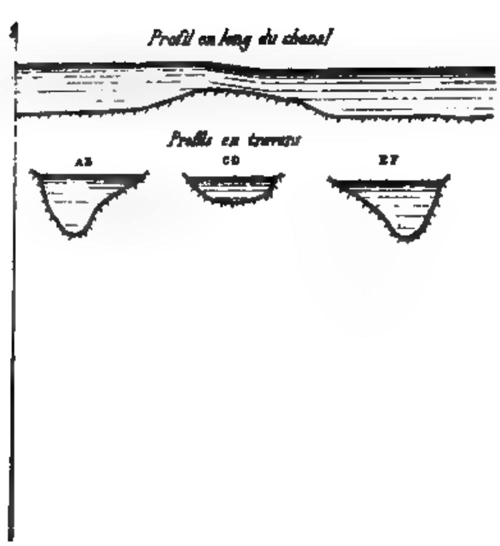
GIRARDON.

Inscriptions souvent répétées.	*Häufig vorkommende Inschriften.*	*Words frequently repeated.*
Altitudes.	Wasserstande.	Altitude.
Chenal.	Fahrrinne.	Channel.
Comparatif.	Vergleichend.	Comparative.
Digue.	Damm, Deich.	Dike, dam.
Echelle.	Maasstab.	Scale.
Epis.	Buhnen.	Groins.
Etiage.	Niedrigster Sommerwasserstand.	Low water.
Hauteur.	Höhe.	Height.
Insubmersible.	Unüberschwemmbar.	Insubmersible.
Longueur.	Länge.	Length.
Longueurs partielles.	Theilweise Längen.	Partial lengths.
Normales kilométriques.	Kilometrische Normallinien.	Normal lines 1 km. in length.
Perré.	Steindamm.	Stone dam.
Profil en long.	Längsprofil.	Longitudinal section.
" " travers.	Querprofil.	Transverse "
Traverse.	Qüerbuhne, Querdamm.	Cross-dike.



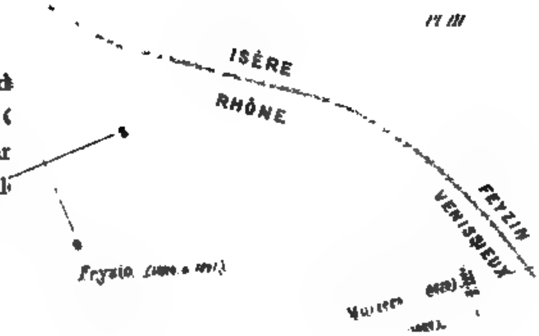
Pl.II

Passage type N°2

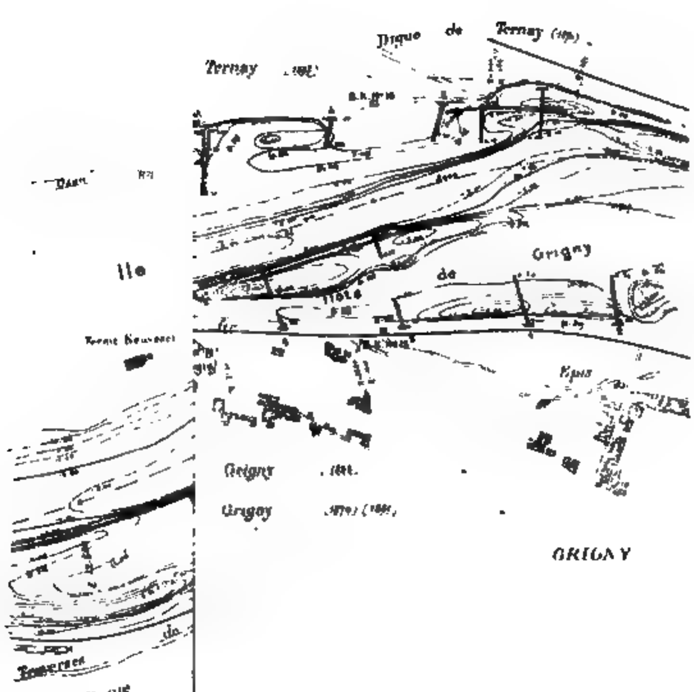


Pl. III

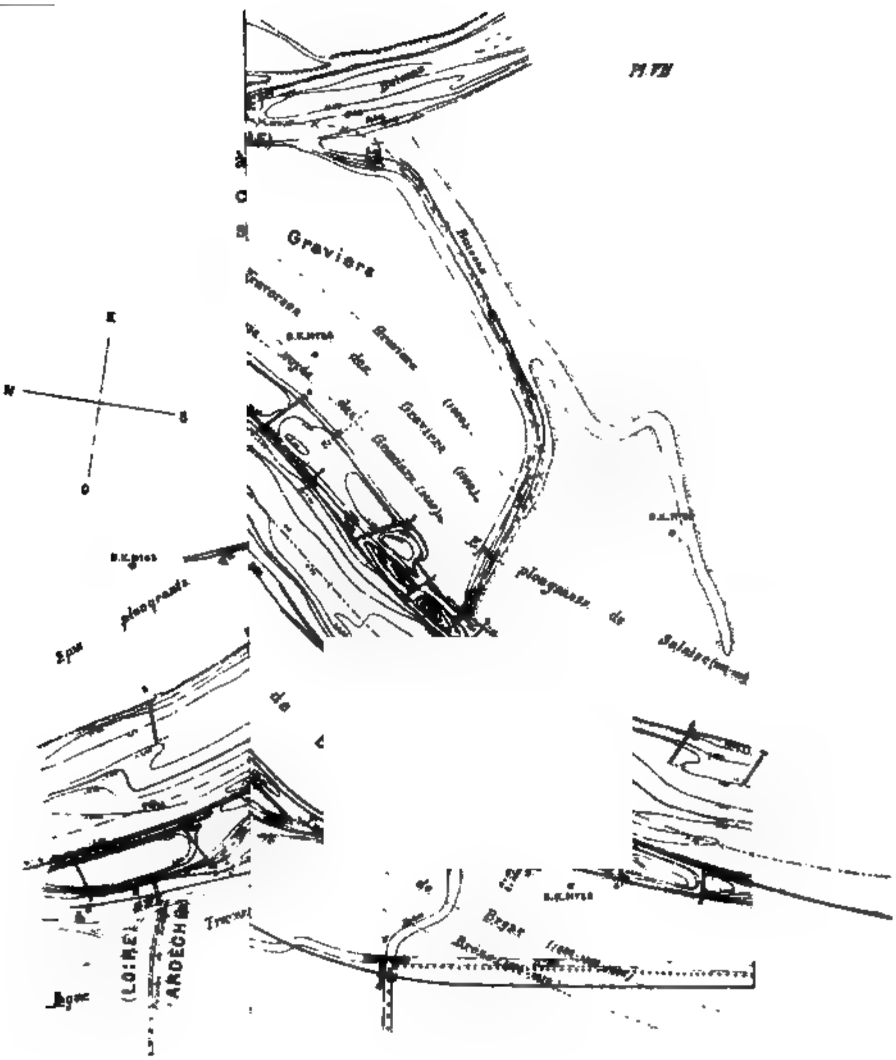
»Les d
à $\frac{2}{5}$. (
consultar
sont cell



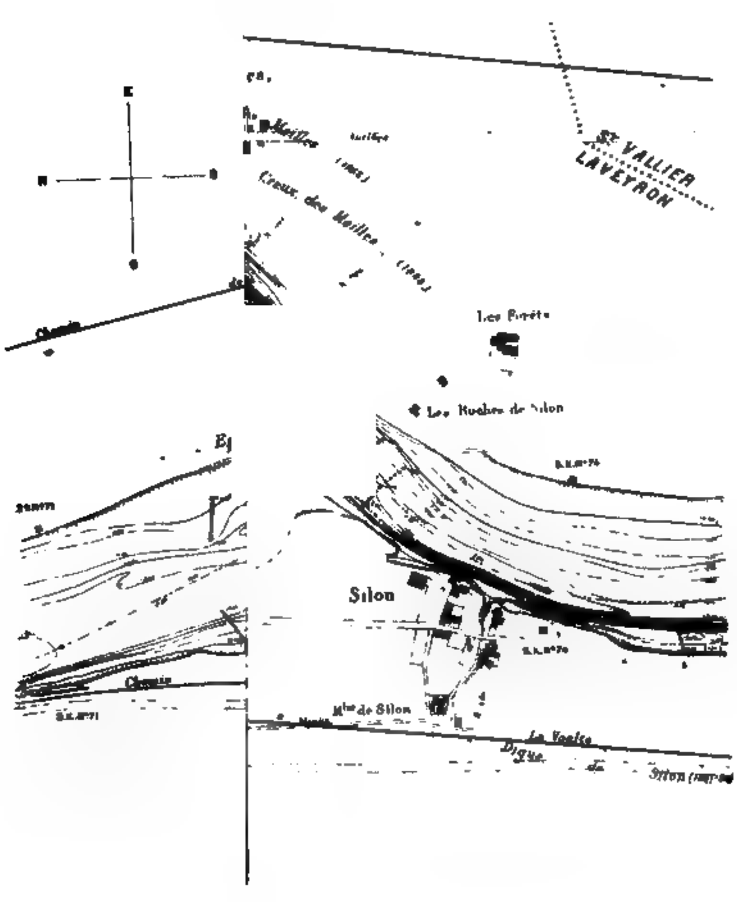
Pl. IV



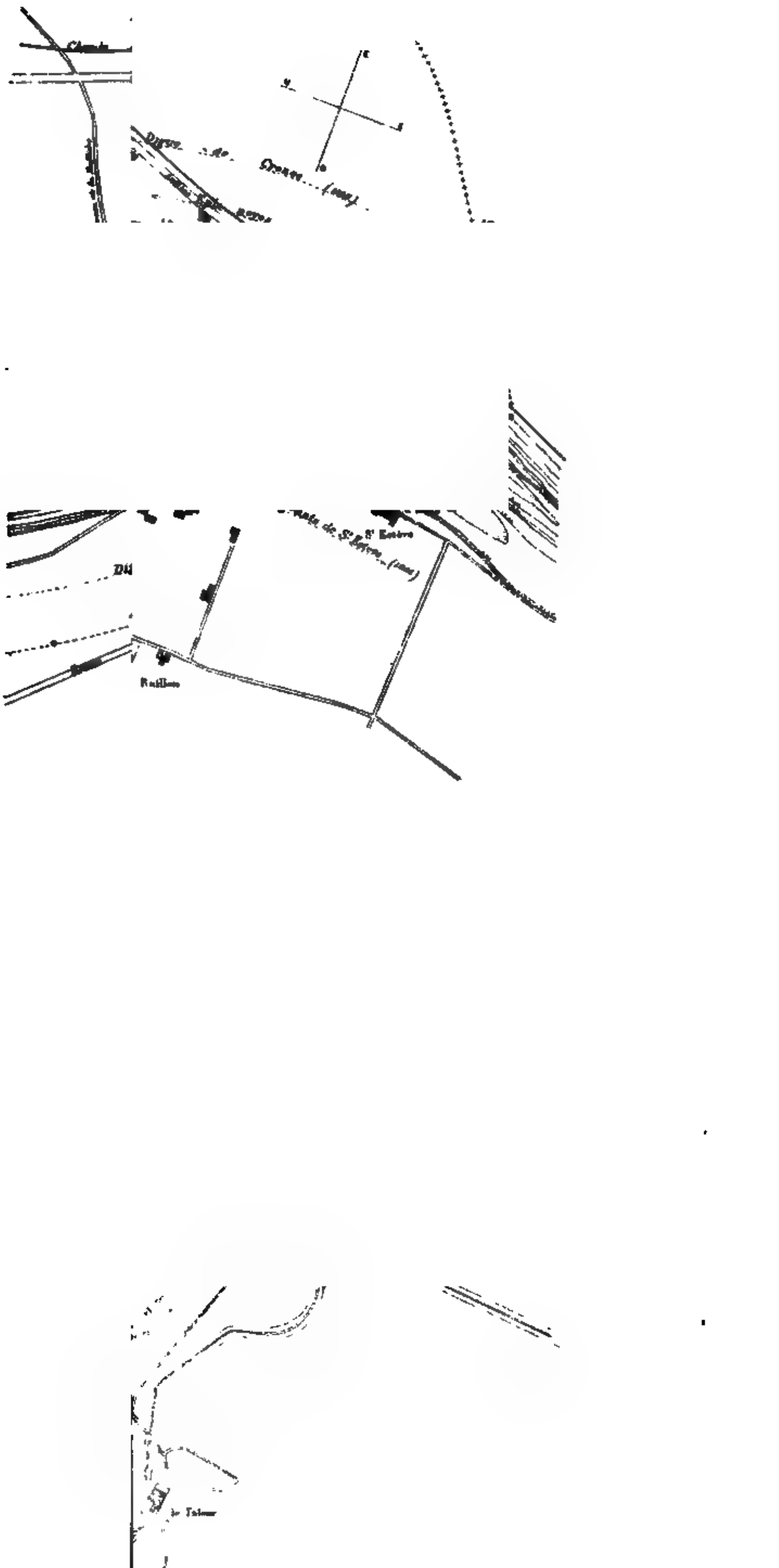
Pl. VII

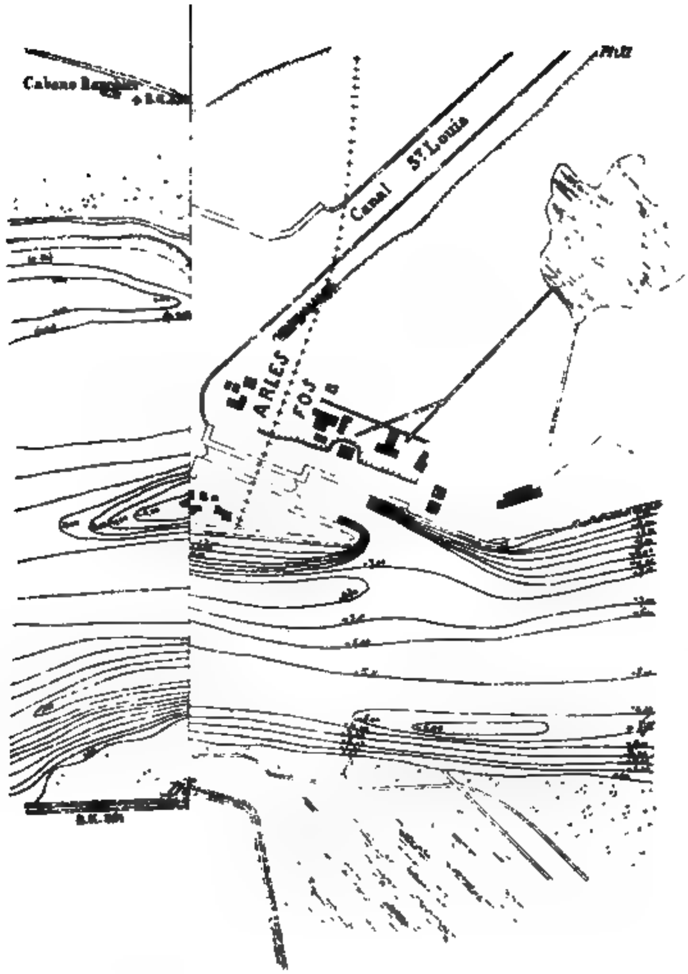


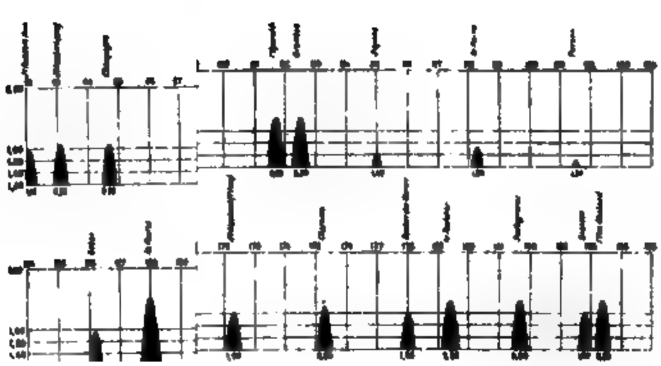
Pl. VIII



Pl. IX

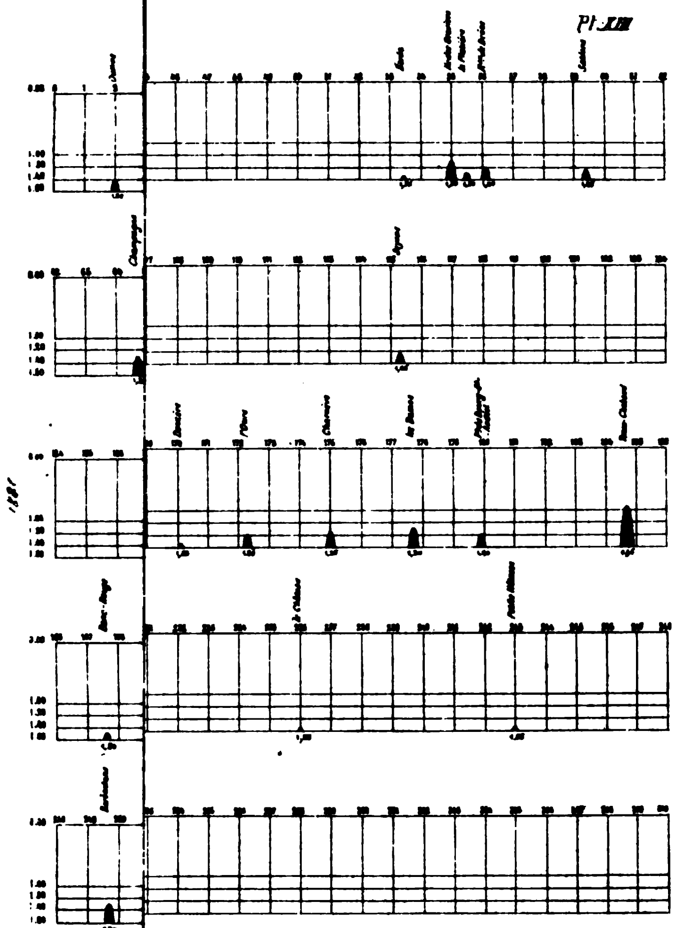



Canal St. Louis
ARLES
FOS

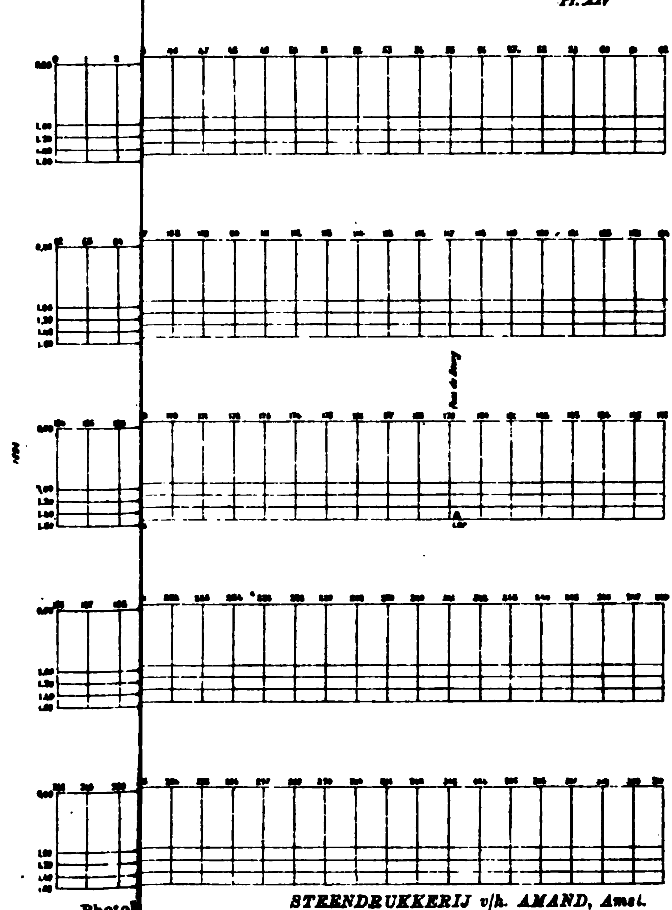


qui

Pl. XIII



Pl. XIV



Photol

STEENDRUKKERIJ v/h. AMAND, Amst.

32

VI[th] INTERNATIONAL INLAND NAVIGATION CONGRESS.
THE HAGUE, 1894.

7[th] QUESTION.

REGULATION
OF
RIVERS AT LOW WATER.

REPORT

BY

PH. W. VAN DER SLEYDEN. (*)
Chief Engineer of the Waterstaat at Maastricht,

AND

R. J. CASTENDIJK,
First-class Engineer of the Waterstaat at Nijmegen.

THE HAGUE,
Printed by Belinfante B[ths], late A. D. Schinkel,
PAVELJOENSGRACHT, 19.

1894.

(*) Since the month of May M. VAN DER SLEYDEN has been appointed Minister of Waterstaat.

VI[th] International Inland Navigation Congress.

THE HAGUE, 1894.

Regulation of rivers at low water.

REPORT

BY

Ph. W. VAN DER SLEIJDEN,
Chief Engineer of the Waterstaat at Maastricht.

AND

R. J. CASTENDIJK,
First-class Engineer of the Waterstaat at Nijmegen.

INTRODUCTION.

On every river we distinguish between a summer and winter bed.

The summer bed comprises that part of the bed of the river which as a rule during the summer months is covered with water and consists of coarser and finer elements, which are liable to displacement under the influence of changing conditions of water.

The peculiar characteristics of the winter bed are that it is a sufficient height above the summer bed and remains sometimes during several consecutive months free from water. It can therefore produce vegetation and obtain more firmness of surface, so that when the water does stream over it, it is only by exception that holes are formed in it or that any solid part of it is carried away.

The slopes which join the summer bed and the winter bed are, even on the same river, sometimes steep, sometimes of slight incline, but nearly always plainly perceptible. It is in vain, when looking at a river, to seek for any other plainly visible distinctions between low and high water than that above-named between summer bed and winter bed.

As long as the river remains in its natural state, the summer bed is liable to continual alterations of its course, and the winter bed to decrease on the one haud and to increase on the other, for the stream works upon the slopes of the winter bed at many points. The loosened elements are carried over some distance and then form an increase of the winter bed at a place, where the working of the stream is less powerful.

31,005 with 9,155,496 tons (cubic metres) in 1892. The quantity of goods imported and exported by way of Lobith was in 1892 a total of 6,312,870 tons, out of which to or from Rotterdam 2,661,496 to or from Nijmegen, Tiel, Gorinchem and Dordrecht, together 263,554 and to or from Belgian harbours 1,447,016 were carried on the Waal.

All goods sent from or to Amsterdam, and other Dutch harbours go by way of the Lower Rhine and the Lek.

The dimensions of the large ships that navigate the Rhine at the present time are

Length	81 m.
Width.	10.5 "
Depth.	2.5 "

Burden 1500 tons (cubic metres.)

At Krimpen on the Yssel a short time ago there was built for a German firm a tug with a length of 88 m., width 10.5 m., depth 2.6 m. and a carrying power of 1800 tons.

Water level and discharge.

The following table shows the high and low water-levels and other particulars concerning the character of the Waal.

	Lobith.	Hulhuizen.	Nijmegen.	Tiel.	St. Andries*).	Zaltbommel.
	Above N.A.P. m.	Above N.A.P. m.	Above N.A.P. m.	Above N.A.P. m.	Above N.A.P. m.	Above N.A.P. †) m.
Highest known water-level with open river in this century 4th to 6th January 1883. .	16.38	15.19	13.42	9.63	8.08	7.09
Average summer level (1st May to 1st November 1871 to 1880	11.13	10.35	8.77	5.57	4.40	3.39
Average low level corresponding to 1.50 m. above zero at Cologne (Protocol of the Central Commission of the navigation on the Rhine, 1st October 1885).	9.60	9.13	7.52	4.32	3.00	2.08
Lowest level in September 1893	9.12	8.61	7.06	3.67	2.39	1.55
Lowest known water level with open river	8.77	8.21	6.64	3.54	2.39	1.23
	15 Nov. 1874.	15 Nov. 1874.	15 and 16 Nov. 1874	26 and 29 Oct. 1814	27 Sept. 1893.	30 Oct. 1832.
Distance from the frontier. .	4.2 km.	11.9 km.	26 km.	56.6 km.	67.8 km.	76.7 km.
Fall per km. at average summer level		0 1013	0.1128	0.1075	0.1045	0.1135
Fall per km. at the low level of September 1893		0.0662	0.1107	0.1104	0.1143	0.0943

*) At St. Andries observations were first begun in 1854.
†) N.A.P. = New Standard of Amsterdam.

The division of the water at the point where the Upper Rhine divides into two branches, the Waal and Pannerden canal, is so arranged that of the entire quantity of water two thirds is received by the first named and the rest by the latter. At all events this is what was declared as desirable by the States of Gelderland, Holland, Utrecht and Overijssel in 1745; and it is still always endeavoured to maintain it so.

In reality, the quantity of water from the Upper Rhine received by the Waal is rather more than two-thirds, especially at times of low water.

According to observations which have been made nearly every year, the distribution of the water has not undergone any important change the last sixty years.

The quantity received by the Waal at high water-levels is about 6,200 cubic metres, at the average summer level (1871—80) about 1,400 cubic metres, and at the lowest water level (with open river) about 500 cubic metres per second.

Regulation of the summer bed.

In 1850 a beginning was made to improve rivers in the Netherlands. Until that year only insolated works had been effected and mostly in the interest of the owners of the banks.

The improvements effected in the period from 1850 to 1874 consisted in connecting central points with one of the banks, limiting superfluous width, and removing projecting banks or other obstructions from the normal river-bed. The width temporarily accepted in 1866, regulated for the summer bed, was 360 m. from Pannerden to Zaltbommel, increasing to 400 m. from the latter place to Loevestein.

After 1874, the work of bringing the regulated summer bed to the required width by means of groins or by dams of which the tops emerged above the average summer level was continued.

In 1888 this work was completed.

Thus a great improvement was both obtained in the interests of the river and of the navigation.

For navigation, however, the improvement was not complete, as in some points, for instance in the straight sections and where the current is passing from one side of the river to the other, there was not found sufficient depth at times of low water.

Though at the time of the original regulation the dicharge of water and ice was the primary object, more attention was paid later to the interests of navigation.

The requirements of navigation were therefore now submitted to a fresh examination with the result that it was decided that a continuous depth for navigation of 3 m. at average low water level, corresponding

to about 1.25 m. below the average summer level, and given in the foregoing table, over a suitable width of the river-bed, was essential for shipping of large tonnage on the Rhine.

In curved sections the depth of the navigable channel or *thalweg* along the concave banks was very satisfactory and considerably above the average; in the straight or nearly straight sections, as well as at the turning points, the depth presented was the average of the depth over about the entire width of the profile, and this was insufficient. The deduction was made that in the last named sections the requisite depth could not be obtained so long as the regulation width accepted in 1866 was adhered to, but that a contraction would be necessary in the sections.

The equation

$$b = \frac{A}{c\sqrt{d^3\alpha}},$$

in which A represents the discharge per second in cubic metres, b the regulation width, c a constant $= 50$, d the average depth and α the incline, shows that by substituting different values for A, d and α, the regulation width in the straight sections should be 310 m. for a discharge of 870 cubic metres per second at the low water-level referred to, and would differ only a few metres refrom this amount for a discharge of 1,400 cubic metres at the 1.25 m. higher average summer level.

The contraction here referred to, while still preserving as much as possible the existing width in the curves, has been effected on the Waal by lengthening the existing groins (see note respecting question N°. 6).

To the increased length of these groins a height has been given corresponding to the average water-level, while the tops of the existing works were more or less high.

Use of low dams.

The confining of the river-bed between two parallel dams, with their summits *below the lowest water-level*, could not in the case referred to have led to the desired result, unless the distance of these dams from one another was accepted at considerably less than 310 m.

In determining the distance from one another at which these dams should be laid in order that the required depth, as mentioned above, may be obtained, we have in the above equation to take for A, the discharge at the lowest water-level (with open river), estimated at 500 cubic metres, and for the average depth 2.25 m. because this lowest water-level is about 0.75 m. lower than the average low-water level above referred to, corresponding to about 1.25 m. below the average summer level (see table *supra*).

tion :

$$\frac{)0}{^{3} \times 0.00011} = 282 \text{ m.}$$

t water-levels would thus depend on the
ed of a width of 360 m., or of a second
m., enclosed between two parallel dikes
elow average low water, or on a regulated
of the dams be brought to the average
as appears by the calculation, may be
th of three metres below the average
mined above to be necessary.
r bed would not generally be the same as
ion bed, but repeatedly cross it, because
ould in the curves have to approach the
much as possible from the depth to be

ter possible in the low summer bed, the
it would have to be connected at certain
uely to the groins or the shores which

fficulties.

water bed between two parallel dams
be obtained in favour of a regular
, the plan here considered of parallel
ow water is not to be recommended:
pense of construction, as well as of main-

of building them;
inconvenience submerged works cause to
iling vessels and fishing craft.
is the general disadvantage inseparable
dams, namely, that the sand which is
ty of settling as it does between the

in the way shown under *b*, viz. by means
eight of average low water at a distance
though less damaging to navigation and
ation in the regulation of the Waal on

uch higher than it was for the work that
gthening the existing groins to the new

regulation line. The average distance between these groins is 200 m.

The execution of this contraction by 50 m. only necessitated therefore over 200 m. of the river in length the laying of 50 m. of groins; while for the application of the parallel dam system, for 200 m. length of river a dam of at least 200 m. would have been required, not including the necessary connections with the existing groins.

Against the disadvantage here recounted, the advantage of a more perfect direction of current through the parallel dams is not of sufficient weight.

Besides this, on account of the great mobility of the bottom, which consists chiefly of sand mixed with a very little coarse gravel, there would be a danger at times of high water of choking up the smaller channel between the two dams, especially at points where the direction of the full stream in the river-bed does not coincide with that of the low summer bed.

Conclusion.

It appears from the above that we may base the conclusion that a regulation with submerged parallel dams for low water-levels is not to be recommended, at all events not on the Waal.

THE MAAS.

Incline.

In southern Limburg, where the Maas on the greatest part of its length forms the division between the Netherlands and Belgium, the incline is about 0.40 m. per km.; this section is about 60 km. long. The current is here very powerful and the bed consists exclusively of gravel, of which the largest pieces have a measurement of 0.15 m.

Then follows another section of about 40 km. in length, on which the incline regularly decreases.

In northern Limburg between Venloo and Mook over a distance of about 60 km., the incline is only 0.06 per km.

The bed here consists of fine gravel and sand.

The condition of the river in southern and northern Limburg is thus very different.

In the followiug pages we shall, where necessary, expressly state which part of the river is referred to, while the middle section is left out of our review.

Widths.

The widths of the summer bed of the river in its naturel state vary in southern Limburg from 60 m. to 130 m., and in northern Limburg from 90 m. to 180 m., that is when sand-banks and vegetation showing just

above the average summer level is regarded as belonging to the winter bed.

Winter bed.

Over by far the greatest part of the length of the river the winter bed rises from 3 m. to 5 m. above the average summer level and is connected with a slope of about 3 in 1 with the border of the summer bed or with recent deposits.

Discharge.

The discharge of the Maas in southern Limburg is about 125 cubic metres per second at the average summer level and about 320 cubic metres per second at the average winter level.

It occurs almost every winter during one or more days that the state of the water is such that the discharge is more than 1000 cubic metres; and the largest known discharge may be placed at at least 2200 cubic metres per second. During long or short periods in the summer the discharge is reduced to 50 cubic metres per second, and less.

The smallest discharge may be reckoned at about 25 cubic metres per second, of which about 6 cubic metres per second are drawn off at Maastricht. For northern Limburg these quantities are increased by 10 %
to 15 %.

Water levels.

In southern Limburg the average winter level is nearly 1 m., and in northern Limburg from 1.50 m. to 2 m. above the average summer level.

In southern Limburg the lowest river levels sink to about 80 centimetres and in northern Limburg to about 1.20 m. below the average summer level.

The highst levels rise 5 m. to 5.50 m. above the lowest levels; while in northern Limburg the difference is 8 m. or at most 10 m.

Depth of Channel.

The Maas in southern Limburg is in its present condition as a rule navigable for vessels of 0.80 m. or more draught in the spring and in the autumn.

In the summer the navigable depth generally decreases to less than 0.50 m. In the exceptionally dry summer of 1893 there was only a depth of 0.25 m. In northern Limburg the navigable depth is generally 1.20 m., or more, and seldom less than 1 m. In the summer of 1893 it decreased, however, to 0.60 m.

Regulation of the summer bed.

Since 1850 regulation works have been executed on those sections of the river which were most in need of them. In 1866 the regulation

width of the summer bed in southern Limburg was fixed at 100 m. and in northern Limburg at 120 m. This regulation is, however, far from being completed. In the beginning the tops of the parallel dams and the groins were made very little higher than the summer level, but were later on raised, so that they now reach nearly to the average winter level; and consequently their favourable effect has been improved.

The incline, however, still shows many irregularities. This must be principally ascribed to the fact that up to the present almost nothing has been done towards the regulation of maximum discharches, so that the velocity varies exceedingly in the various sections and is the cause of the continuation of the irregular displacement of gravel and sand.

Use of low dams.

Whatever expectations we may have with regard to the usefulness of a regulation system for rivers at low levels, there can be no question of the execution of works for this object before the regulation of the summer bed, and of the profile at higher water-levels is further advanced than it is at present.

This, however, need not prevent us from entering upon a consideration of the works which might have to come under notice in the execution, and of the results which might have been expected to occur.

In the curved river sections there is now already hollowed out a deeper channel along the concave banks on the summer bed.

By means of low dams it will be possible to enclose these channels within steeper walls, still these are not necessary for the preservation of the channel and their influence on the condition of the river will be of small importance. It is more particularly the question, whether by placing low dams at certain distances from each other in the straight sections and in the turning points of the river, where as a rule the summer bed is of nearly enough the same depth over all its width and therefore a deeper channel is necessary, a channel can be obtained and maintained, which would connect itself in a suitable manner with the channels already existing above and below the curved sections.

Let us first examine what the condition is of the normal summer bed without the deeper channel and what measurements could be given to the channels in question.

On the Maas in southern Limburg the width is $b = 100$ m., and the incline $\alpha = 0.0004$. If now $C = 50$ be taken for the value of the constant, the discharge at average summer level will be $A = 125$ cubic metres per second, the depth

$$d = \sqrt[3]{\frac{A^2}{c^2 b^2 \alpha}} = \sqrt[3]{\frac{125^2}{50^2 \times 100^2 \times 0.0004}} = 1.16\text{m} .$$

and the velocity

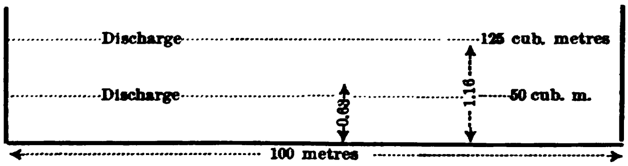
$$v = c\sqrt{d\,\alpha} = 50\sqrt{1.16 \times 0.0004} = 1.08 \text{ m.}$$

If the discharge A be reduced to 50 cubic metres, the depth becomes

$$d = \sqrt[3]{\frac{50^2}{50^2 \times 100^2 \times 0.0004}} = 0.63 \text{ m.}$$

and the velocity

$$v = 50\sqrt{0.63 \times 0.0004} = 0.795 \text{ m.}$$



If it is required that the depth d_1 be $= 1$ m. in a channel enclosed by low dams, with an discharge $A = 50$ cubic metres per second, the breadth of the channel now becomes

$$b_1 = \frac{A}{c\sqrt{d^3\,\alpha}} = \frac{50}{50\sqrt{1^3 \times 0.0004}} = 50 \text{ m.}$$

and [the velocity

$$v_1 = c\sqrt{d_1\,\alpha} = 50\sqrt{1 \times 0.0004} = 1 \text{ m.}$$

If now the discharge A again increases to 125 m. per second, the water level will rise about 0.60 m. so that $d_1 = 1.60$ m., and there will be carried off by the deeper channel

$$A_1 = c\sqrt{b_1^2\,d_1^3\,\alpha} = 50\sqrt{50^2 \times 1^3 \times 0.0004} = 101.2 \text{ cub. m.}$$

with a velocity

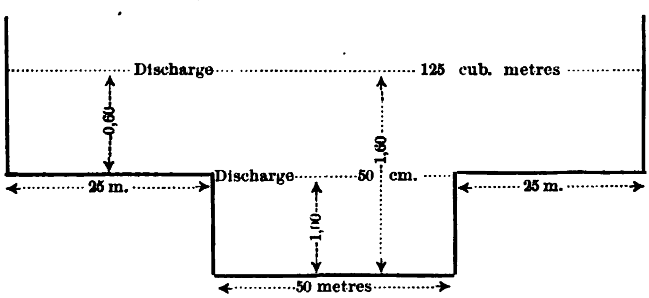
$$v_1 = 50\sqrt{1.60 \times 0.0004} = 1.265 \text{ m.}$$

while on the remaining width of the summer bed $b - b_1 = b_2 = 50$ m., where the depth is $d_2 = 0.60$ m. will be carried off

$$A_2 = c\sqrt{b_2^2\,d_2^3\,\alpha} = 50\sqrt{50^2 \times 0.60^3 \times 0.0004} = 23.8 \text{ cub. m.}$$

with a velocity of

$$v_2 = 50\sqrt{0.60 \times 0.0004} = 0.775 \text{ m.}$$



For the Maas in northern Limburg we obtain the following results.

On the normal summer bed with a width of b = 1.20 m. and an incline α = 0.00006 the depth for the average summer level, with a discharge A = 140 cubic metres per second will be

$$d = \sqrt[3]{\frac{A^2}{c^2 b^2 \alpha}} = \sqrt[3]{\frac{140^2}{50^2 \times 120^2 \times 0.00006}} = 2.085 \text{ m.}$$

and the velocity

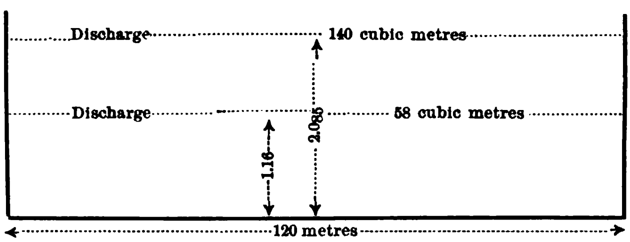
$$v = c \sqrt{d \alpha} = 50 \sqrt{2.085 \times 0.00006} = 0.56 \text{ m.}$$

If the discharge A be diminished to 58 cub.metres the depth becomes

$$d = \sqrt[3]{\frac{58^2}{50^2 \times 120^2 \times 0.00006}} = 1.16 \text{ m.}$$

and the velocity

$$v = 50 \sqrt{1.16 \times 0.00006} = 0.42 \text{ m.}$$



If it be now required that the depth d_1 be = 2 m. in a channel confined by low dams with a discharge A = 58 cubic metres per second, the breadth of the channel becomes

$$b_1 = \frac{A}{c \sqrt{d^3 \alpha}} = \frac{58}{50 \sqrt{2^3 \times 0.00006}} = 53 \text{ m.}$$

and the velocity

$$v_1 = c \sqrt{d_1 \alpha} = 50 \sqrt{2 \times 0.00006} = 0.55 \text{ m.}$$

If now the discharge A increases to 140 cubic metres the water level will rise about 1.08 m., so that d = 3.08 m., and there will be carried off by the deeper channel

$$A_1 = c \sqrt{b_1^2 d_1^3 \alpha} = 50 \sqrt{53^2 \times 3.08^3 \times 0.00006} = 111 \text{ cubic metres.}$$

with a velocity

$$v_1 = 50 \sqrt{3.08 \times 0.00006} = 0.68 \text{ m.}$$

while on the remaining width of the summer bed $b - b_1 = b_2 = 67$ m. where the depth is d_2 = 1.08 m., will be carried off:

$$A_2 = c \sqrt{b_2^2 d_2^3 \alpha} = 50 \sqrt{67^2 \times 1.08^3 \times 0.00006} = 29 \text{ cubic metres.}$$

limited to a very small amount, does it become possible to maintain any given channel in the summer bed. It is, however, scarcely necessary to remark that for the attainment of this result such extensive and costly bottom-dressing would be required, that there could seldom or never be question of such work, and it may thus be left out of consideration.

CONCLUSION.

From the above it appears that the building of low parallel dams must be considered as premature, until by regulation of the summer bed and of the profile for higher levels a continuous channel has been formed; while, even after such a channel has been formed, it remains quite uncertain what would be the increase of depth which might then be obtained by laying low dams. If we consider in addition the expense both of construction and maintainance of low dams and the danger they cause to navigation, which difficulties we have more fully dwelt upon above while treating of the Waal, it must be concluded that neither on the Maas can the building of low dams be regarded as an efficacious means of improving the depth necessary for navigation at low water.

As a means of obtaining the greatest possible depth for navigation with a minimum discharge, the canalisation of the river is much to be preferred for it attains its object with more certainty and in the end perhaps is not more expensive.

The forming of a lateral canal fed by the river is also a subject worthy of consideration.

(Translated by G. J. Rowland.)

33

VIth INTERNATIONAL INLAND NAVIGATION CONGRESS.

THE HAGUE, 1894.

7th QUESTION.

The Chataracts of the Dnieper

BY

V. E. DE TIMONOFF,

Court counseller,

Engineer of the ways of Communication. Professor of the Imperial Institute for Engineers of the ways of Communication.

THE HAGUE,

Printed by Belinfante Bros, late A. D. Schinkel,

PAVELJOENSGRACHT, 19.

1894.

FRANÇOIS DE WOLLANT,

INGÉNIEUR HOLLANDAIS,

auteur du premier projet d'amélioration des cataractes du Dniépr.

THE RAPIDS ON THE DNIEPER

BY

Y. E. DE TIMONOFF,

Engineer of Ways and Communications,

Professor at the Institute of Ways and Communications, St. Petersburg,

Member of the Commission for the creation of commercial ports in Russia.

INHALT:

THE HAGUE,

Printed by Belinfante Bros, late A. D. Schinkel,

— 1894. —

DEDICATED

TO THE MEMORY OF

THE DUTCH ENGINEER,

LIEUTENANT-GENERAL

FRANCIS DE WOLLANT,

DIRECTOR-GENERAL OF WAYS AND COMMUNICATIONS IN RUSSIA.

CHAPTER I.

General description of the river.

Contents: § 1. Importance of the Dnieper. — § 2. Hydrography. — § 3. Commerce.

§ I. Importance of the Dnieper.

No river which traverses the vast plains of Russia is more intimatety connected with the history of the country than the Dnieper.

Like the Rhine in Germanic traditions, the Dnieper plays a prominent part in many of the exploits of ancient Russian heroes and in the oldest legends.

The waves of this beautiful river have heard the early songs that wept for the sorrows of Igor and his brave companions. They have seen the golden headed naiads enticing by their magic voices the belated traveller to the depths of the abyss, while the coil spirits on the other hand beckon him from the dark recesses of a neighbouring forest.

Later, following the majestic course of the same river, Oleg leaves Kiev, reaches the Black sea and appears before the walls of Constantinople. The valorous conqueror nails his shield to the doors of the imperial palace and after concluding a glorious peace with the Byzantine Emperor, he returns to Kiev, on the banks of the Dnieper, and makes the city his capital.

During the same epoc Constantine Porphyrogenetus, in his administrative treatise, gives a very clear description of the Lower Dnieper and the navigation which plied upon it.

It was also about this time that a great princess erected the first Christian cross.

Centuries then succeeded, centuries of desolation, of misery and süffering. Barbarous flags float victorious on the holy waters which formerly bore the ships of Igor, Oleg and Sviatoslao.

The Dnieper seemed lost to Russia.

But the efforts of a great Emperor, succeeded by an Empress worthy of him, created a fleet of war-ships which not only restored to Russia what she had lost, but opened up new countries for her.

Thus the Dnieper became for ever a river flowing through the interior of Russia.

The commercial relations which existed through the Dnieper as far back as the tenth century between Kiev and Bygantium were revived with renewed vigour and under a different system.

But the same obstacle, the rapids which interfered with the first boats to descend the Dnieper still barred the route.

Among the first reforms undertaken during the reign of Catherine II in this part of Russia, the works for the regulation of the rapids on the Dnieper occupy an important place.

Neither these works nor those which succeeded them obtained the desired results, and for more than a century the original problem, viz. the regulation of the section between the towns of Ekaterinoslav and Alexandrovsk in order that it might be accessible to navigation against the current, has not yet been solved.

The importance however of obtaining this solution has only continued to increase.

The basin of the Dnieper is 527.000 square kilometres in extent and with its tributaries embraces 14 governments (fig. 1). The total length of the waterways of the system of the Dnieper utilisable for floats and navigation is about 13,466 versts (1) (14,365.3 Km.), of which 9,061 versts (9,666.1 Km.) are navigable.

This immense system is barred by the rapids a few hundred kilometres from the Black Sea, where the Dnieper having received all its most important tributaries reaches its maximum.

Moreover the construction of a great number of railways through the basin of the Dnieper, the development of agriculture and industry in the south of Russia, the discovery of remarkable beds of iron-ore and coal in the neighbourhood of Ekaterinoslav, etc. render the establishment of an uninterrupted navigable way to the two seas, the Baltic and the Black Sea, a matter of the highest importance.

On account of these and other reasons His Excellency the Minister of Ways and communications, M. A. C. Krivohchéive, has taken steps

---

(1) 1 verst = 1.06678 kilometre = 0.66288 English mile.
1 verst = 500 sagènes.
1 square verst = 1.138 square kilometre.
1 sagène = 7 Englisch feet = 84 inches = 12 quarters of an archine = 48 verchoks = 2.13356 metres.
1 cubic sagène = 9.2121 cubic metres.
1 pud = 16.38 Kilogrammes.
1 ton of 1000 Kilogrammes = 61.048 puds.

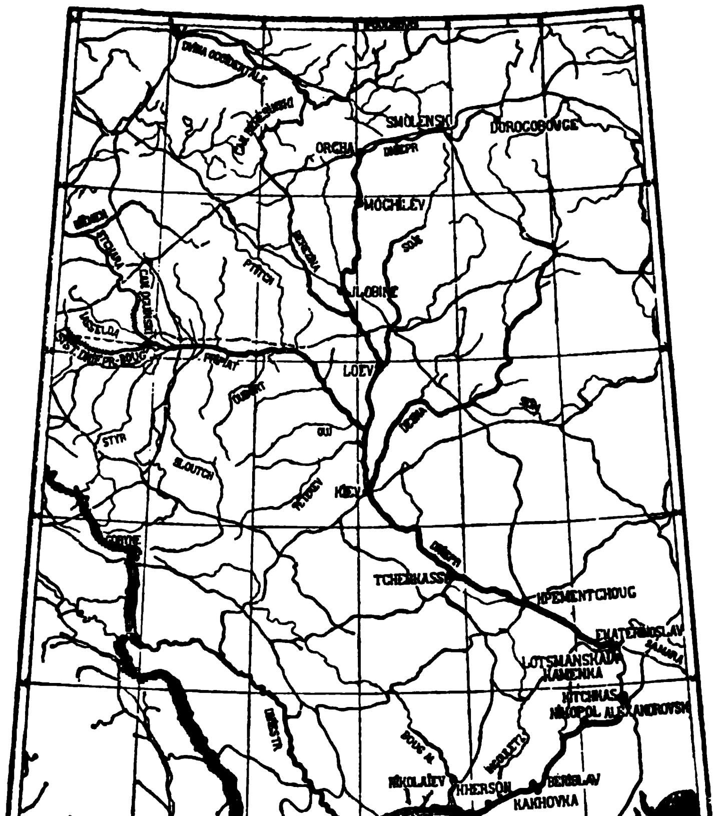


Fig. I. — Map of the Dnieper and its tributaries.

***N.B.** The section between Ekaterinoslav and Alexandrovsk, where the rapids present themselves and navigation is only possible down stream, is marked by a single line.*

for the resumption of the study of the methods for regulating the cataracts of the Dnieper.

Honored with the direction of these studies, I have thought that a brief account of the question presented to me would perhaps not be without interest to the members of the Sixth Inland Navigation Congress, and I have hoped also that after reading this account they will kindly throw such light upon the situation as they can, as has been donc in former Congresses with respect to other questions concerning Russia.

§ 2. Hydrography of the Dnieper.

The depth of the Dnieper varies greatly throughout its course and it is impossible to give an average for each section. Numerous shoals, ridges of sand and rock, etc. cause shallow and dup places to appear in close proximity. Thus between Kiev and Ekaterinoslav the depth in times of low water falls in same places to 74 cm., while in the same section it reaches in other places depth of 20 m.

The velocity of the current, although variable, is not a serious hindrance to navigation, except in the section which includes the rapids, where it is so great that it is next to impossible for vessels to make way against the current.

Floods occur once a year, in the spring, and last a comparatively short time. They increase the discharge to an enormous degree, which varies for the section including the rapids from 300 cub. m. (at low water) to 17,000 cub. m. during a high flood (fig. 2).

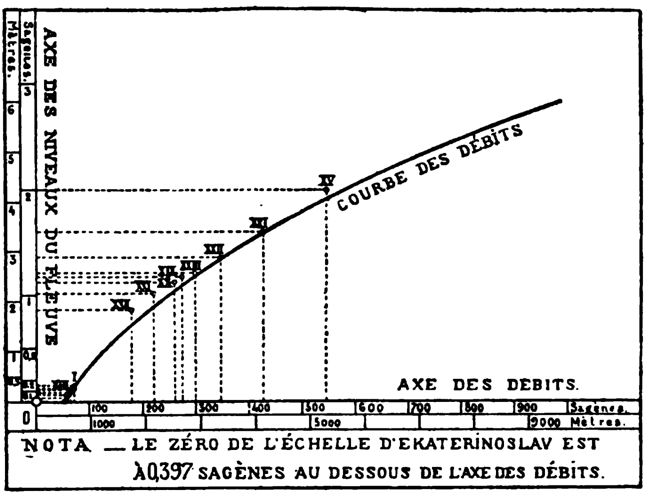


Fig. 2. — Diagram showing the variatiouns in the discharge of the Dnieper near Ekaterinoslav in 1882—83.

The periods during which navigation is possible vary for different parts of the watercourse. Near Smolensk it is hardly 200 days; at Kherson there is an average of 277 days (figs. 3, 4).

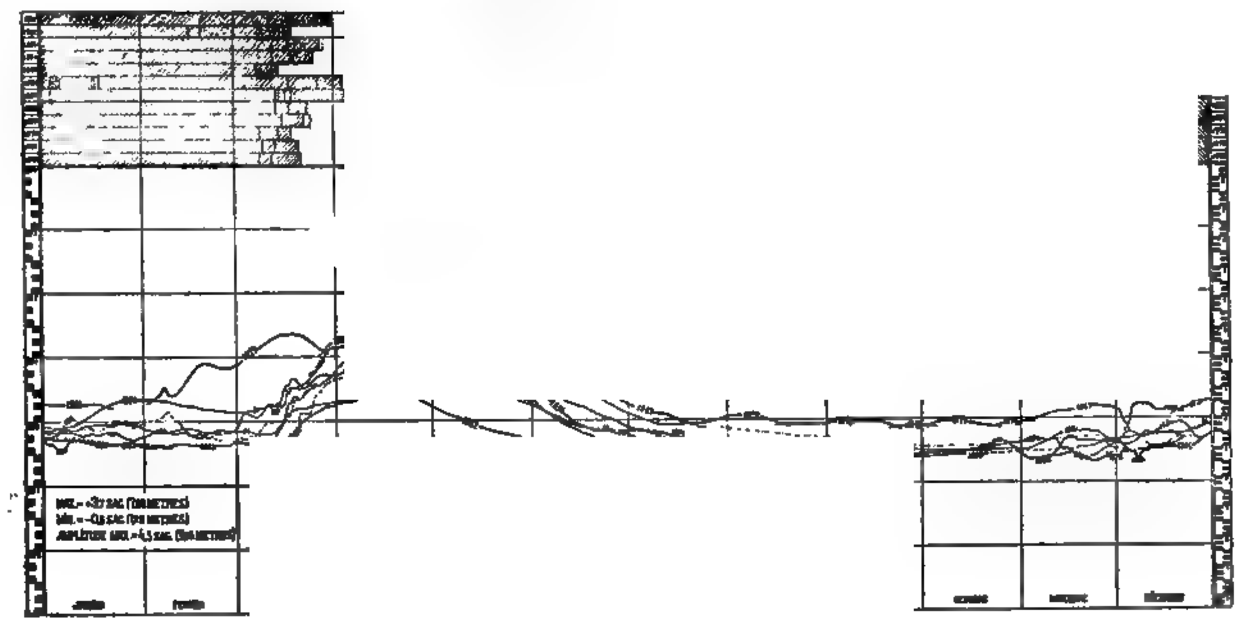


Fig. 3 and 4. — Diagram showing the variations in the water-Level and the length of time the river is free from ice at Setamanskaia Kamenka (diluvial section).

N.B. The cross-hatching in fig. 4 indicates the periods during which the river is covered with ice. The vertical lines show when the ice formed and broke up.

The Dnieper is connected by means of three systems of canals and canalised rivers with the basins of the Western Duna, the Niemen and the Vistula, but these waterways are now only used for the transport of timber, for the most part in floats.

The enormous system of navigable ways included in the basin of the Dnieper is blocked at a few hundred kilometres from the Black Sea by a large number of rapids which form a section 66.7 Km. in length and present an insurmountable barrier to vessels ascending stream and render navigation extremely dangerous with the current.

§ 3. Commerce.

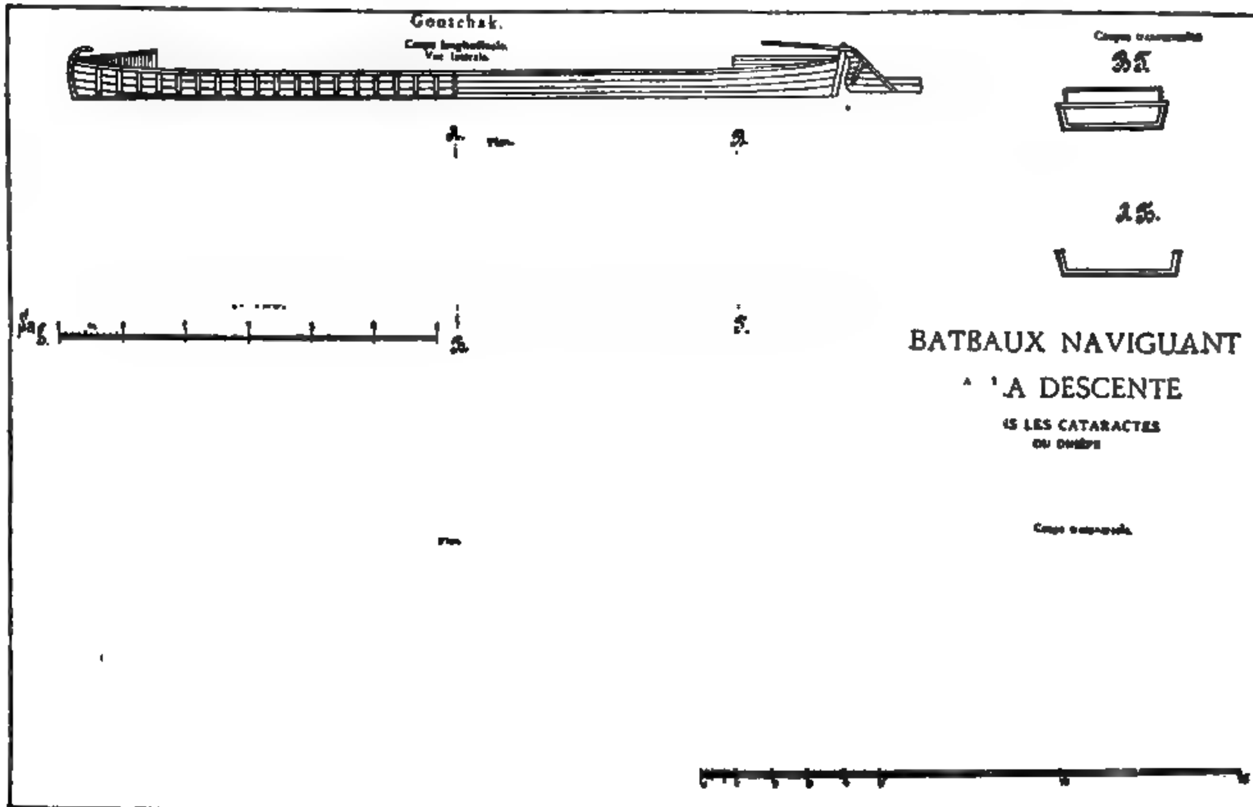
In spite of the very favourable situation of the Dnieper basin and the waterways which pass through it, commerce although considerable falls far short of the development which it whould assume if the different hindrances which limit its extension were removed.

The rapids divide the Dnieper system into two distinct sections. The upper of these comprises more than 9000 kilometres of navigable ways and is almost isolated, for the artificial waterways which connect it with the Baltic hardly admit of the transport of timber in floats and the rapids can only be passed by vessels going down stream. Moreover it is only possible to short the rapids during a short period every year and the operation is attended with much loss on account of stoppages, damages sustained, the absence of insurance, heavy pilot expenses, etc.

Floats of wood to the number of 500 to 600, a few hundred boats of inferior build (fig. 5—20) go down the rapids every year, carrying in all some 100,000 tons.

Consequently there is no commercial movement in the opposite direction. Therefore the Lower Dnieper between Alexandrovsk and the mouth, a distance of 347 Km., or about $^1/_{25}$ of the upper section, surpasses it completely in commercial activity. Such is the result of direct communication with the sea.

This state of things has the most unfortunate influence upon boat building on the Dnieper, since boats having once descended the rapids from the upper to the lower section are unable to return to their original ports.



Figs. 5, 6, 7, 8, 9, 10, 11, 12. — Boats used in the descent of the rapids on the Dnieper.

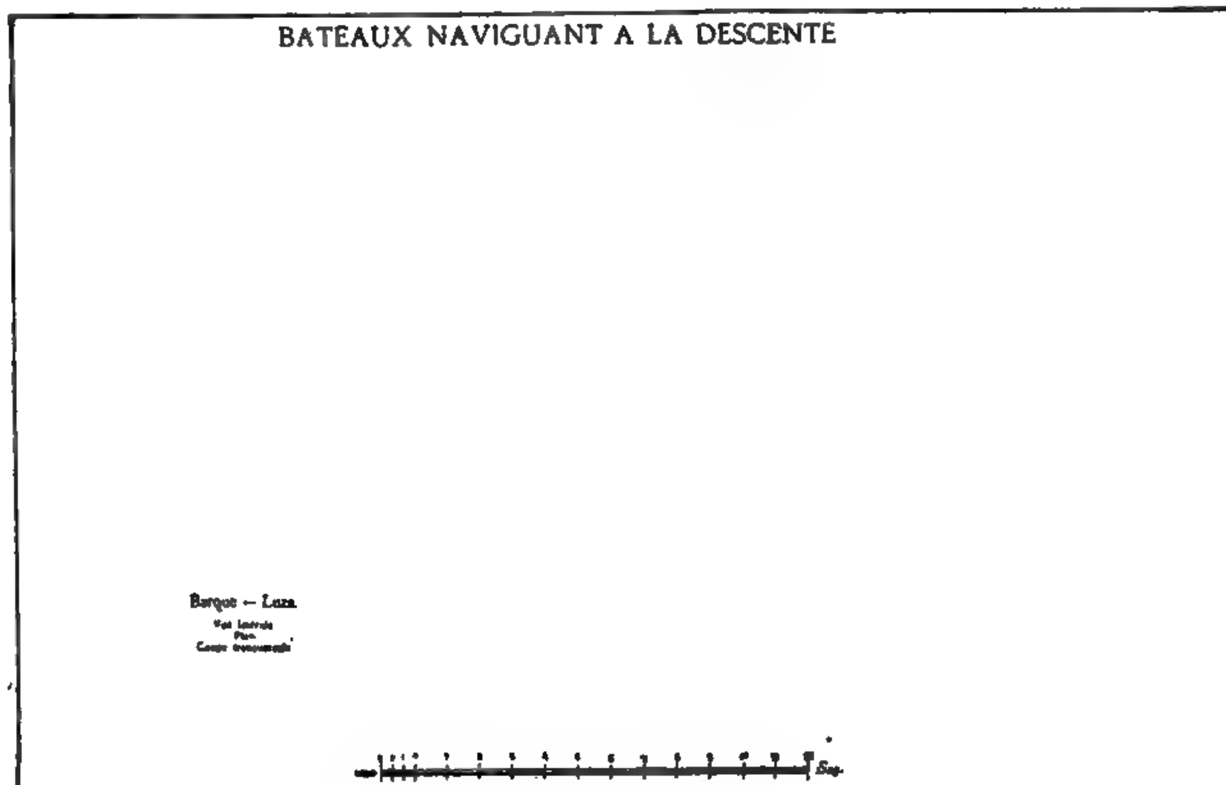


Fig. 13, 14, 15. — Boats used in the descent of the rapids on the Dnieper.

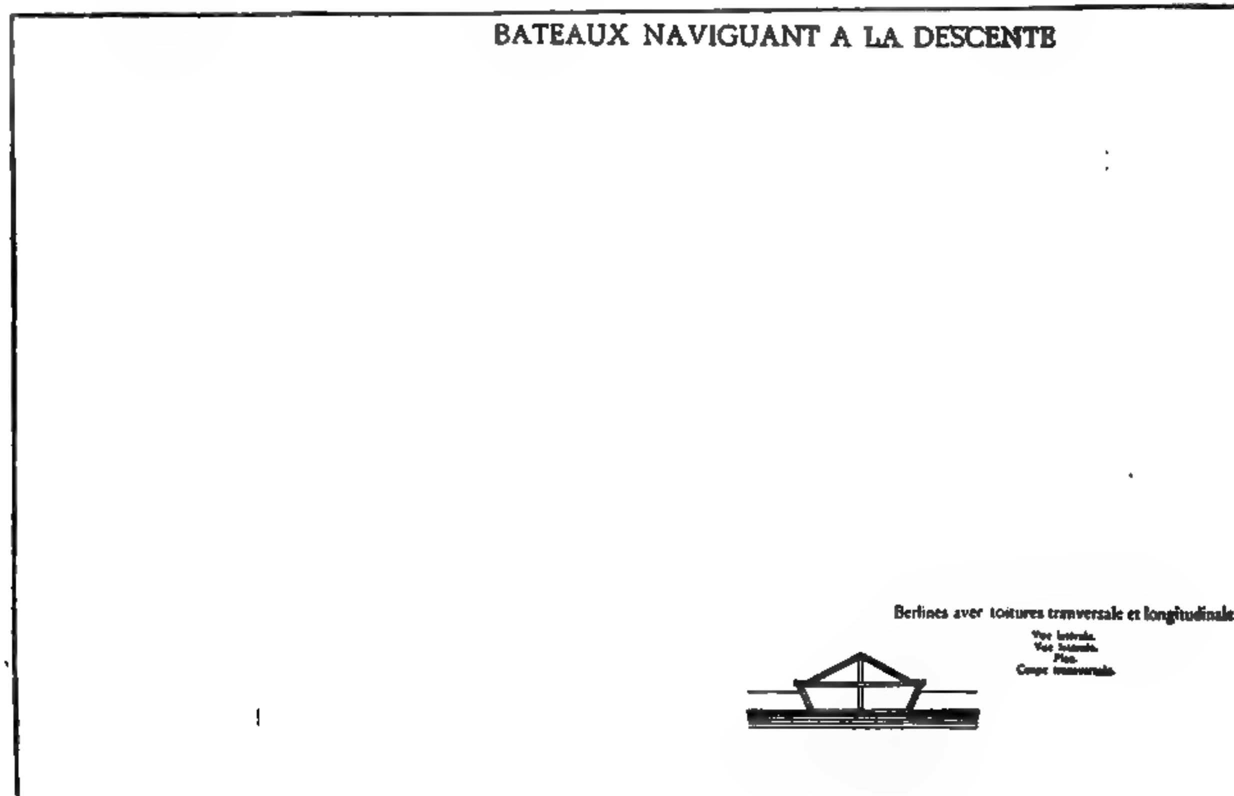
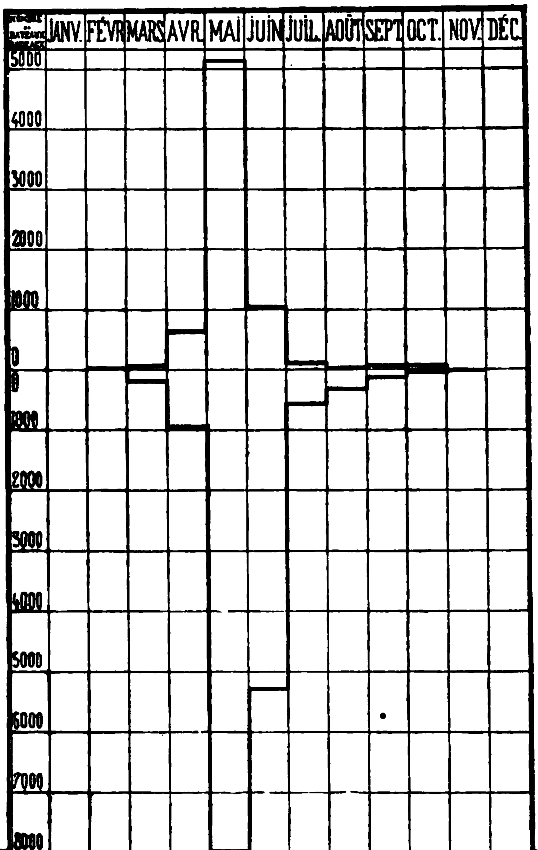


Fig. 16, 17, 18, 19, 20. — Boats used in the descent of the rapids on the Dnieper.

TABLEAU GRAPHIQUE DU MOUVEMENT DES BATEAUX ET DES TRAINS DE BOIS À TRAVERS LES CATARACTES DU DNIEPR EN 1852–1879.



		JANV.	FÉVR	MARS	AVR.	MAI	JUIN	JUIL.	AOÛT	SEPT	OCT.	NOV.	DÉC.	TOTAUX
TOTAUX	BATEAUX	·	3	51	619	5131	1023	90	27	52	58	-	·	S. 7054
	RADEAUX	·	·	183	944	7994	5289	569	319	124	35	1	·	S. 15458
MOYENNES			0.11	1.82	22.11	183.25	36.54	3.21	0.96	1.86	2.07	·	·	s. 251.93
ANNUELLES			·	6.54	33.71	285.5	188.89	20.32	11.39	4.43	1.25	0.04	·	s. 552.07

Fig. 21. — Diagram of the movement of boats and timber floats over the rapids of the Dnieper between 1852 and 1879.

CHAPTER II.

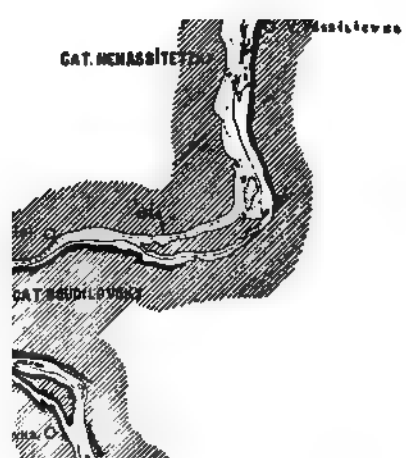
Brief description of the principal rapids between Ekaterinoslav and Alexandrovsk.

Contents: § 4. Names of the principal rapids. — § 5. Channels in the diluvial section of the Dnieper. — § 6. Characteristics of the rapids: length, fall, incline, etc. — § 7. The Old Kodak. — § 8. The Sowra. — § 9. The Cuvette. — § 10. The Résonnante. — § 11. The Insatiable. — § 12. The Volnigi. — § 13. The Boudiloo. — § 14. The Superflue. — § 15. The Libre. — § 16. Pilots on the Dnieper.

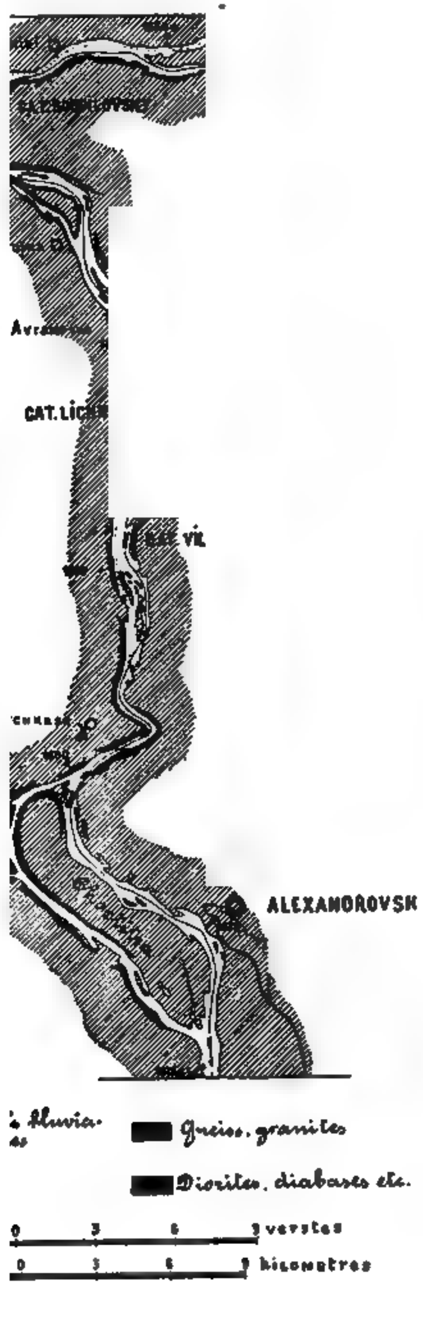
§ 4. Names of the rapids.

The principal rapids of the Dnieper, which may be divided into nine groups, extend over a distance of 62½ versts (67,7 Km.) in the government of Ekaterinoslav (figs. 22, 23, 24, 25). Their total fall amounts to 15,723 sagènes (33,49 m.). They come in the following order:

The *Staro-Kodakski*	rapid	(OldKodak).
„ *Sourski*	„	(Soura).
„ *Lokhanski*	„	(Cuvette).
„ *Zwolnetski*	„	(Résonnante).
„ *Nenassytetski*	„	(Insatiable).
„ *Volnigski*	„	(Volnigi).
„ *Boudilovski*	„	(Boudiloo).
„ *Lishni*	„	(Superflue).
„ *Vilny*	„	(Libre).



Figs. 22 and 23. — Map of the diluvial section of the Dnieper between Ekaterin



lexandrovsk drawn from data furnished by the Ministry of Ways and Communications and the mmittee.

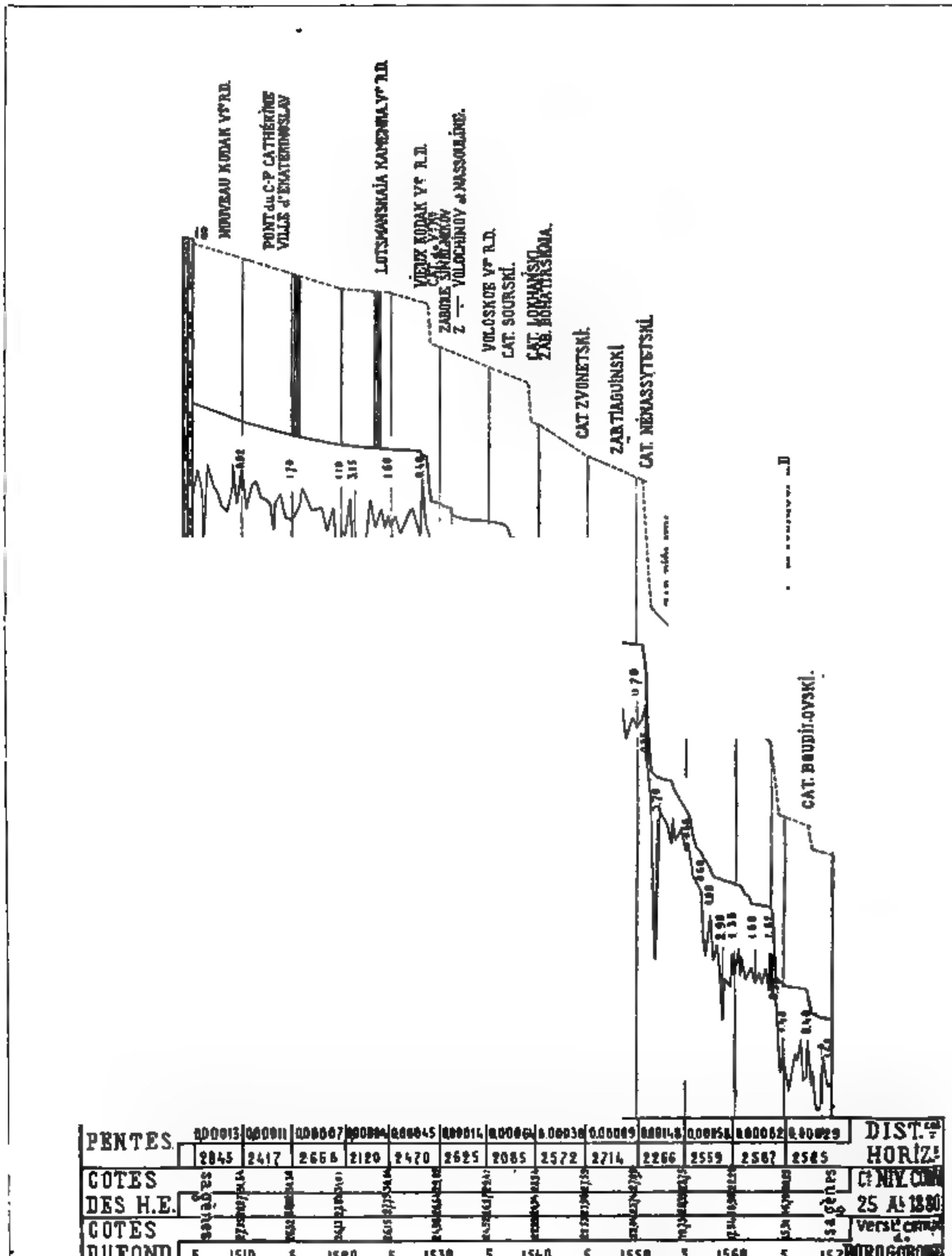
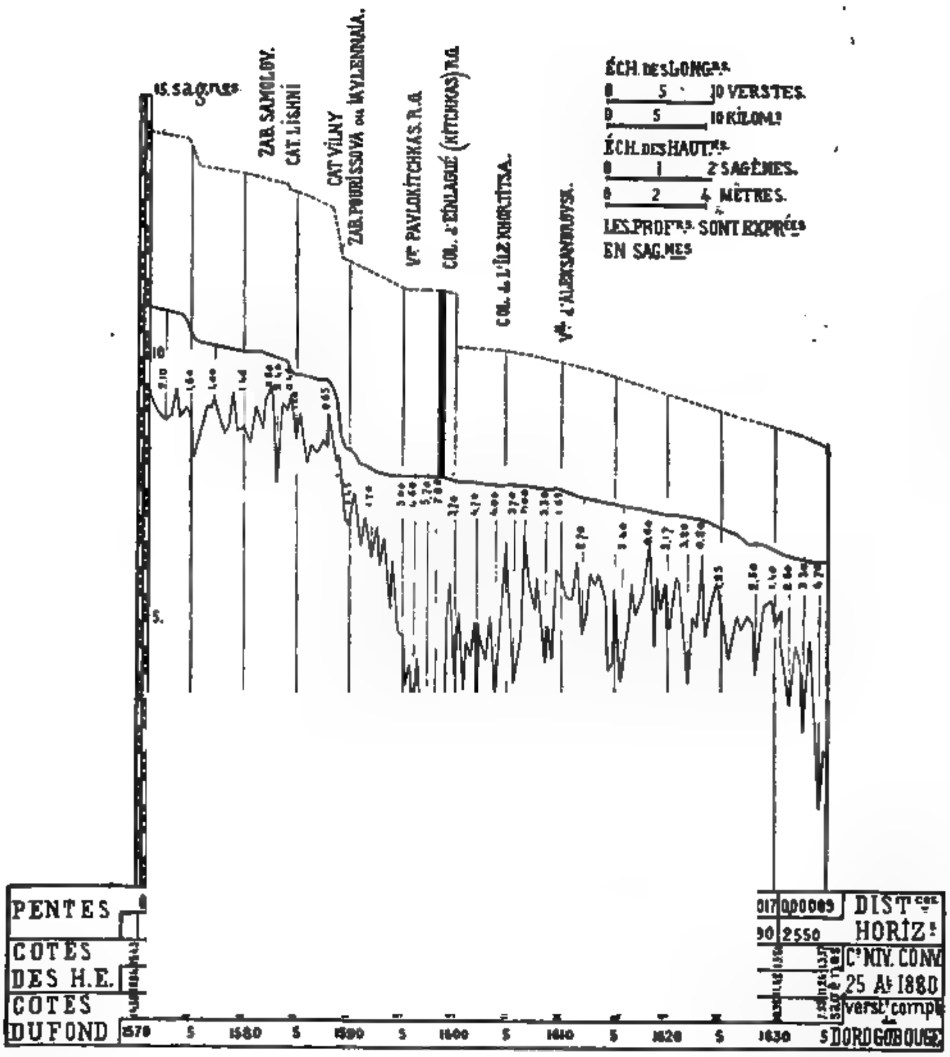


Fig. 24 and 25. — Longitudinal sectio

N.B. The fall lines indicate the bottom and the surface a



of the diluvial section of the Dnieper.

low water level; high water is indicated by te dotted line.

§ 5. Channels in the diluvial section of the Dnieper.

The diluvial section of the Dnieper has two channels known as the „old" and the „new". The „old" channel, which is also called the Cossak's channel, keeps near the right bank for the greater part of its course and passes by the places least encumbered by rocks. The depth from 2 to 4 m. in the hollows falls at low water to 1 m. and even 0.50 m. in the rapids.

When the water is low (— 0.60 s. = — 1.28 m.) quantities of stones emerge and render the movement even of timber floats impossible.

The „new" channel lies for the most part near the left bank. It passes by the canals, which will be referred to later (§ 22). Between the rapids the two channels frequently coincide.

The depth of the „new" is greater than that of the „old" channel. It reaches 0.50 s. (1.07 m.) below low water level.

The entrance to the canals is often difficult on account of the numerous rocks which have not yet been removed. Nevertheless the creation of this artificial channel has lengthened the period during which navigation is possible by an average of one month.

Timber floats are able to make use of the new channel when insurmountable obstacles would be met with in the old channel. But when the water is very low the new channel also becomes impracticable.

The period during which navigation is possible in the rapids even for timber floats going down stream, is therefore always much shorter than either above or below the rapids.

Fig. 26. — Plan of the Staro-Kodakski rapid (Old Kodak) showing General de Wollant's passage (near the right bank), the diked passage (left bank) and the position of the rocks removed in 1883—1884 (middle).

§ 6. Characteri…

TABLE SHOWING THE MEAN LENGTH, FALL AND INCLINE OF THE RAPIDS …

№	NAMES OF THE RAPIDS.	THE OL…				
		Length in Sagènes (metres).	Low water.		Conventional low water.	
			Fall in Sagènes (metres).	Average incline.	Fall in Sagènes (metres).	Average incline.
1	Staro-Kodakski	290 (619)	0.961 (2.049)	0.0033	0.871 (1.857)	0.[illegible]
2	Sourski	40 (85)	0.257 (0.547)	0.00643	0.24 (0.512)	[illegible]
3	Lokhanski	70 (149)	0.745 (1.587)	0.01064	0.525 (1.120)	0.00[illegible]
4	Zvonetski	140 (299)	0.722 (1.540)	0.0051	0.552 (1.177)	0.00[illegible]
5	Nenassytetski.	408 (869)	2.148 (4.57)	0.0053	2.258 (4.810)	0.00[illegible]
6	Volnigski	392 (836)	1.556 (3.314)	0.00397	1.326 (2.827)	0.0[illegible]
7	Boudilovski	140 (298.20)	0.272 (0.580)	0.00194	0.272 (0.580)	0.00[illegible]
8	Lishni	50 (106.5)	—	—	0.031 (0.0661)	0.00[illegible]
9	Vilny	400 (852)	—	—	0.928 (1.981)	0.00[illegible]
	Totals . . .	1930	—	—	7.003	-

of the rapids.

THE DNIEPER. (TAKEN FROM THE STUDIES OF H. SOULKOVSKI 1887/88).

CHANNEL.		CANALS.						
High water.		Length in Sagènes (metres).	Low water.		Conventional low water.		High water.	
Fall in Sagènes (metres).	Average incline.		Fall in Sagènes (metres).	Average incline.	Fall in Sagènes (metres).	Average incline.	Fall in Sagènes (metres).	Average incline.
0.451 (0.962)	0.00156	208 (444)	0.774 (1.649)	0.00372	0.684 (1.459)	0.0034	0.264 (0.563)	0.00122
—	—	—	—	—	—	—	—	—
0.125 (0.267)	0.00178	125 (267)	0.823 (1.753)	0.00658	0.613 (1.308)	0.0049	0.213 (0.454)	0.00170
0.272 (0.580)	0.002	112 (239)	—	—	0.583 (1.244)	0.0039	0.356 (0.759)	0.0032
		Upper Canal.						
1.828 (3.983)	0.0448	200 (427)	0.206 (0.439)	0.0010	0,206 (0,439)	0.0010	0.206 (0.439)	0.0010
		Lower Canal.						
		545 (1163)	2.329 (4.961)	0.00427	2.439 (5.203)	0.0046	2.009 (4.286)	0.0037
1.216 (2.589)	0.00310	221 (472.5)	1.233 (2.626)	0.00056	1.003 (2.140)	0.0045	0.893 (1.903)	0.00404
—	—	107 (228.1)	0.310 (0.660)	0.00291	0.31 (0.661)	0.0029	—	—
—	—	90 (191.7)	—	—	0.035 (0.070075)	6.00039	—	—
—	—	380 (811)	—	—	1.148 (2.449)	0.003	—	—
—	—	1988	—	—	7.021	—	—	—

VELOCITY OF THE CURRENT IN THE RAPIDS OF THE DNIEPER WHEN THE WATER IS FAIRLY LOW. (TAKEN FROM THE STUDIES OF GENERAL POLYKARPOF. — 1880—82).

№	RAPIDS.	Height compared with low water level (0). Sagènes (metre…	THE OLD CHANNEL OF THE RAPIDS.			THE NEW CHANNEL OF THE CANALS.		
			Maximum.	Mini-mum	Aver-age	Maximum.	Mini-mum	Average.
1	St.-Kodakski	—0.… (—0.555)	(1.214)	(1.005)	(1.124)	(3.230)	(0.292)	At the left of the canal. 1.408 (3.004)
2	Sourski	—0.36 (—0.768)	Old channel. 0.969 (2.067)	0.565 (1.205)	0.742 (2 583)	—	—	—
			Channel of the highwaters. 0.916 (1.954)	0.415 (0.885)	0.649 (1.385)	—	—	—
3	Lokhanski	—0 28 (—0.597)	Old channel. 2.431 (5.187)	0.748 (1.596)	1.744 (3.721)	1.415 (3.019)	0.479 (1.012)	1.197 (2.554)
			Channel of the highwaters. 1.394 (2.974)	0 562 (1.199)	0.985 (2.102)	—	—	—
4	Zvonetski	—0.305 (—0.651)	1.452 (3.098)	0 625 (1.334)	1.085 (2.315)	1.565 (3.339)	0.745 (1.590)	1.162 (2.479)
5	Nenassytetski	—0.445 (—0.950)	1.295 (2.763)	0.734 (1.566)	1.004 (2.142)	Upper canal. 0.670 (1.430)	0,415 (0.885)	0.529 (1.129)
						Lower canal. 1.415 (3.019)	0.996 (2.125,	1.168 (2.492)
6	Volnigski	—0.38 (—0.811)	1.495 (3.190)	0.584 (1.246)	0.99 (2.112)	1.316 (2.808)	0.241 (0.514)	0.897 (1.914)
7	Boudilovski.	—0.34 (—.0725)	1.248 (2.663)	0.475 (1.013)	0.867 (1.850)	1.297 (2.767)	0.341 (0.728)	0.843 (1.799)
8	Lishni	—0.34 (—0.725)	The mean channel near the canal. 0.845 (1.803)	0.414 (0.883)	0 614 (1.310)	0.815 (1.739)	0.316 (0.674)	0.573 (1.223)
9	Vilny.	—0.34 (—0.725)	1.105 (2.358)	0.395 (0.843)	0.81 (1.728)	1.205 (2.571)	0,505 (1.077)	0.825 (1.760)

MAXIMUM INCLINES AT LOW WATER LEVEL (0). (TAKEN FROM THE STUDIES OF M. SOULKOVSKI).

N°.	NAMES OF THE RAPIDS.	The old channel.			Canals.		
		Partial fall. Sag.	Corresponding length. Sag.	Maximum incline.	Partial fall. Sag.	Corresponding length. Sag.	Maximum incline.
1	V.-Kodakski . .	0.426	65	0.00655	0.306	50	0.00612
2	Sourski. . . .	0.214	30	0.00713	—	—	—
3	Lokhanski . .	0.169	15	0.01126	0.545	100	0.00545
4	Zvonetzki . . .	0.169	9	0.01877	0.224	17	0.01317
5	Nenassytetzki .	0.540	41	0.01317	0.465	[illegible]	0.0093
6	Volnigski . . .	0.519	[illegible]	0.00752	0.347	50	0.00694
7	Boudilovski . .	0.156	38	0.00473	0.136	40	0.0034
8	Lichny	—	—	—	0.016	30	0.00053
9	Vilny	0.443	70	0.00633	0.577	100	0.00577

MINIMUM DEPTHS IN THE CHANNELS IN THE DILUVIAL SECTION AT CONVENTIONAL LOW WATER AND WHEN THE WATER WAS AT ITS LOWEST IN 1892. (TAKEN FROM THE STUDIES OF M. SOULKOVSKI).

N°.	ZABORES AND SHOALS.	Minimum depth pared with conv nal low water le	Difference bet conventional lov and the lowest	depths compared with the low waters of 1892.		New channel. Minimum depth pared with the conventional low water level (0).	New channel. Difference between conventional low water and the lowest level.	New channel. Minimum depths compared with the low waters of 1892.	
		Sag.	Sag.	Sag.	Metres.	Sag.	Sag.	Sag.	Metres.
	Above the first rapid.	0.90	0.43	0.47	1.00	—	—	—	—
1	Kodakski rapid .	0.75	0.46	0.29	[illegible]	0.58	0.44	0.14	0.30
	Boutzef *zabore*. .	0.93	0.49	0.44	0 34	—	—	—	—
	Nemetzki reach .	1.16	0.50	0.66	1.40	—	—	—	—
2	Sourski rapid . .	0.98	0.42	0.56	1.19	—	—	—	—
	Bondarev *zabore* .	1.04	0.43	0.61	1.30	—	—	—	—

№	NAMES OF THE RAPIDS, ZABORES

Sag.	Sag.	Sag.	Metres.	Sag.	Sag.	Sag.	Metres.
1.20	0.49	0.71	1.51	0.84	0.48	0.36	0.77
0.61	0.58	0,03	[illegible]	—	—	—	—
1.12	0.53	0.59	1.26	1.0	—	—	—
0.70	0.50	0.20	0.43	1.08	0.49	0.59	1.26
1.15	[illegible]	0.53	1.13	—	—	—	—
0.92	0.53	0.39	0.83	0.69	0.50	0.19	0.40
0.81	0.48	0 33	0.70	0.58	0.41	0 17	0.36
—	—	—	—	0.57	0.38	0.19	0.40
0.75	[illegible]	0.37	0.79	—	—	—	—
0.65	0.39	—	—	0.66	0.39	0.27	0.57
0.50	0.40	0.10	0.21	0.64	0.41	0.23	0.49
0.98	0.55	0.35	0.74	0.80	0.55	0.25	0.53
1.15	0.73	0.42	0.89	1.04	0.73	0 31	0.66
1.03	0.69	0.34	0.72	0.62	0.69	(—)0.07	(—)0.15
0.95	0.69	0.26	0.55	0.95	0.69	0.26	0.55
0.50	0.69	(—)0.19	(—)0.40	0.70	0.69	0.01	0.02
0.56	0.69	(—)0.13	(—)0.28	0.61	0.69	(—)0.08	(—)0.17
1.00	0.60	0.31	0.66	1.23	0.69	0.54	1.15

§ 7· The Old Kodak (Staro-Kodakski).

At 13.2 versts (14.2 Km.) below the town of Ekaterinoslav and 6 Km. from the village of the Pilots Kamenka, opposite the village of Staroï-Kodak, the first rapid, Staro-Kodakski, is met with (figs. 26, 27).

In this region the Dnieper has in time of low water a width of *about one kilometre;* with the mean waters the width becomes 1.51 Km. and during floods a little more. The rapid is formed by several rows of rocks which bar the entire width of the river. The banks reach a height of 20 m. and form promontories which advance in some cases 300 metres into the stream.

The fall of this rapid varies between 0.563 and 2.049 m. according to the time of year and the direction of the channels (§ 6).

N. Ivanoff—Pho.

O. L. Ignatieff-Art-peintre.

LE VIEUX KODAK.

(LA STARO-KODAKSKI).

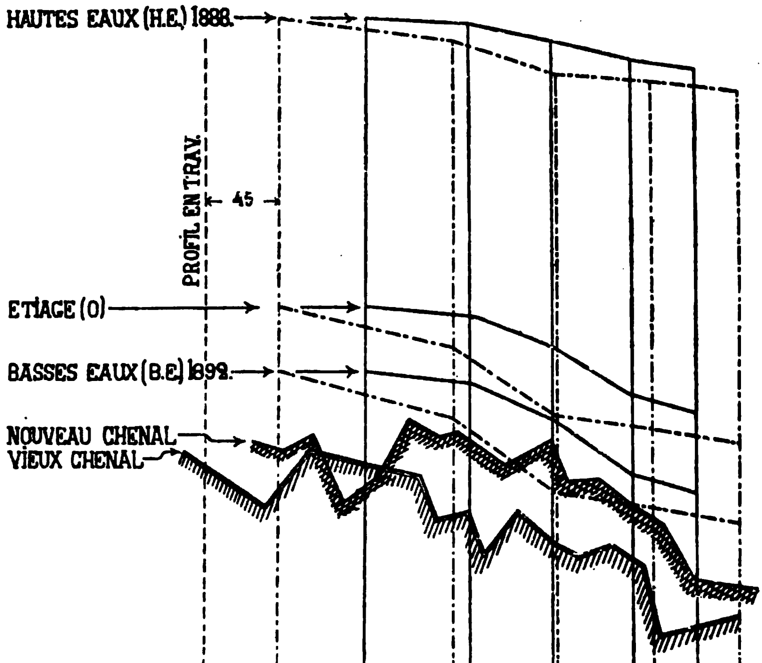
ENTRÉE AMONT DU CANAL.

N. Ivanoff-Pho. O. I. Ignatieff, Art.-peintre.

DÉROCHEMENT À LA DYNAMITE

DANS LA PASSE DU VIEUX KODAK.

[illegible]



VIEUX CHENAL						
DIST. HORI.	SAGENES		110	65	60	55
CHUTES	SAGENES	H.E. 1888.	0,139	0,213	0,054	0,045
CHUTES	SAGENES	0	0,262	0,426	0,099	0,084
CHUTES	SAGENES	B.E. 1892	0,292	0,466	0,109	0,094
PENTES		H.E.	0,00126	0,00328	0,0009	0,00082
PENTES		0.	0,00238	0,00655	0,00165	0,00153
PENTES		B.E.	0,00265	0,00717	0,00182	0,00171

NOUVEAU CHENAL						
DIST. HORIZ.	SAGENES		67	50	50	41
CHUTES	SAGENES	H.E. 1888.	0,024	0,076	0,117	0,047
CHUTES	SAGENES	0.	0,066	0,190	0,306	0,122
CHUTES	SAGENES	B.E. 1892.	0,076	0,220	0,346	0,132
PENTES		H.E.	0,00036	0,00152	0,00234	0,00115
PENTES		0.	0,00098	0,0038	0,00612	0,00297
PENTES		B.E.	0,00113	0,0044	0,00692	0,00322

Fig. 27. — Longitudinal section of the two channels in the Staro-Kodakski rapid (Old Kodak).

Between 1787 and 1800 some of the largest stones were blown up and a canal, 50 sagènes in length, was thus cut along the right bank. To direct the current into this canal a groin, 60 sagènes long, was constructed.

Between 1845 and 1854 a new canal was formed in this rapid near the left bank by means of dikes (v. § 22).

Finally between 1882 and 1884 the rocks in the old channel were blasted by means of dynamite over a width of 30 sagènes (64 m.), which gave this part of the channel a depth of 0.75 sagènes below low water.

The result of the removal of these rocks was to lower the low water level of the rapid by 0.045 sagènes (0.096 m.).

The depth of the new channel presented a minimum of 30 cM. (p. 17). The old channel was principally used in this rapid.

At $2^1/_2$ kilometres below the Kodak rapid there are rocks and stones which project from the right bank for 300 m. towards the middle of the river. Isolated rocks from the left bank join these rows of rock thus forming the Sinelnikovna, Volockinova, Boatzeva and Nassoullina *zabores*.

§ 8. The Soura.

Eight versts (8.5 Km.) below the Kodak rapid is the island of Sourskoï, near the right bank, thus named after the river Soura which here falls into the Dnieper. This island runs parallel to the banks of the river and is joined at its lower end by two ridges of granite 50 sagènes apart. These ridges form the Soura rapid, the fall of which is 0.512 m. (fig. 28).

§ 9. The Cuvette (Lokhanski).

At 1.25 verst (1.33 Km.) below the Soura rapid the continuation of the same granite bottom is met with, where it emerges above the water in isolated rocks and continuous ridges. These masses of rock advance from both banks towards the middle of the stream and end in three small islands of granite formation, thus completely barring the river and forming the Lokhanski rapid (the cuvette). This rapid, with a fall of from 0.267 to 1.753 m., is one of the most dangerous for navigation. It has a canal with dikes on each side, which is not however well situated with regard to the main current.

Pl. 4

Ch. IV.

O. I. Ignatieff, Art.-peintre.

LA CUVETTE.

(LA LOKHANSKI).

TIMONOFF.—Les cataractes du Dniépre.

N. Ivanoff—Phot.

L'Insatiable.

(La Nenassytetski).

Au premier plan le canal à écluses du Général de Wollant.

L'INSATIABLE.

(LA NENASSYTETSKI).

ENTRÉE AMONT DU CANAL INFÉRIEUR.

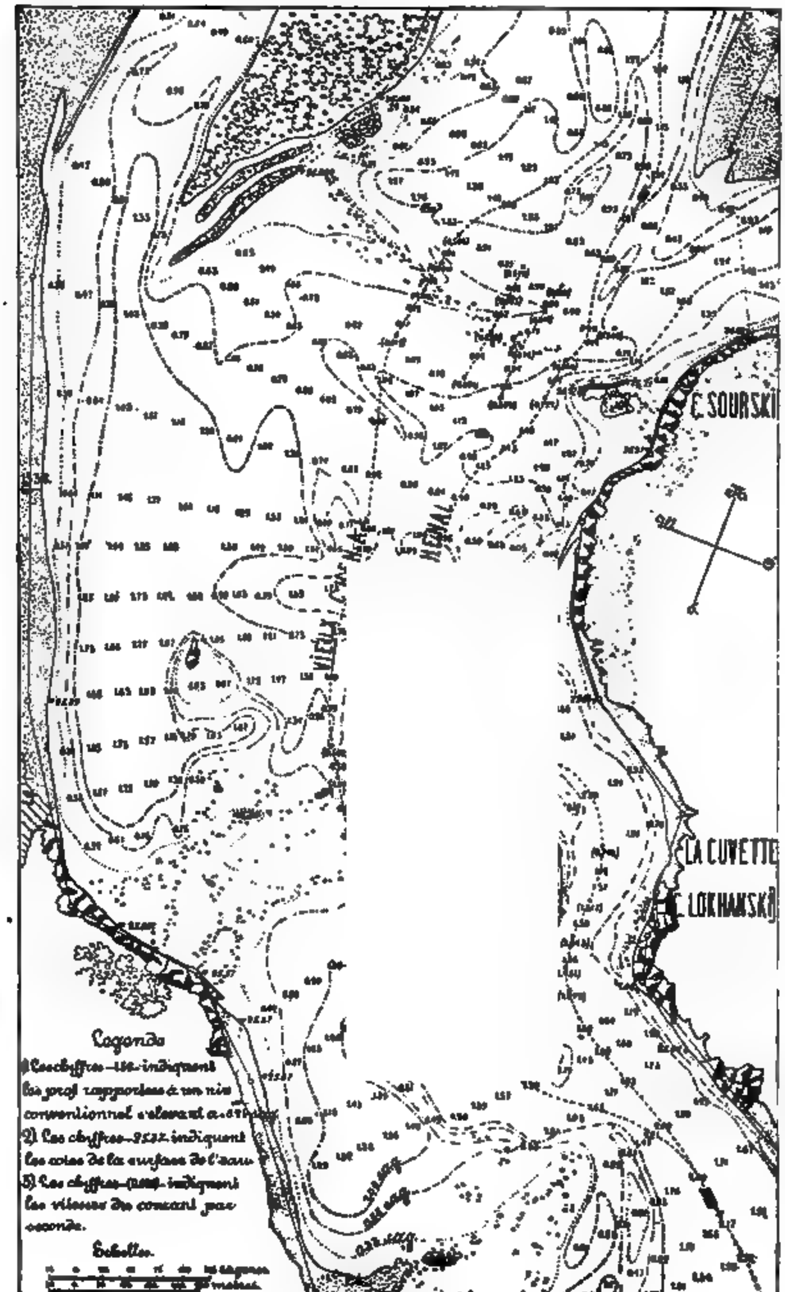


Fig. 28. — Projection of the Sourski and Lokhanski rapids (the Soura and Cuvette).

After the Lokhanski rapid the two channels become amalgamated and continue along the left bank of the river, the right bank being sprinkled for a distance of two versts with a quantity of stones and sand-banks which render navigation impossible. Two ridges and a small island of granite end in this line of rocks, on the left side, and form the Bogatyrskaia or Streletchaia *zabore*.

§ 10. The Résonnante (Zvonetski).

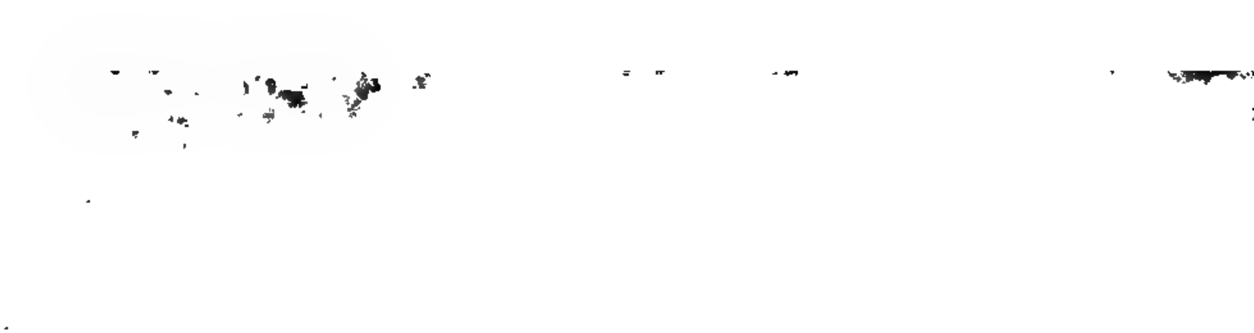
At $4^1/_2$ kilometres below the Lokhanski rapid is the Zvonetski rapid (Résonnante), formed by two ridges of rock some 200 m. apart. The Zvonetski rapid, which has a fall of 0.580 to 1.540 m., has two separate channels: the older of these is open, whille the new one passes through a diked canal. There is a *zabore* known by the name of Glaukhaia about 1 kilometre below this rapid, but as the stones which form it are separated by considerable intervals the only difficulties its presents are due to the shallowness met with over certain isolated stones.

Four versts further on, near the mouth of the little river Voronaia, the Dnieper is divided by a number of islands and becomes $1^1/_2$ verst wide. The channel passes between the last of these islands, the Kozlov, and the left bank. Protected on both sides boats halt in this region and wait for a favourable moment to pass the most dangerous of the rapids, the Nenassytetski. A few separate ridges of rock end on the right side of the island of Kozlov and form the Tiaghinskaia rapid, which has a fall of more than a metre.

As this rapid only bars one of the branches it is generally called a *zabore*.

§ 11. The Insatiable (Nenassytetski).

At a distance of 7 versts 253 sagènes (8 Km.) from the Zvonetski rapid a collection of large rocks is met with on the right bank of the Dnieper; from this point stony ridges stretch right across the river in every direction uniting with numerous islands on the right bank. The current being thus barred and diverted by an immense number of obstacles scattered over a distance of nearly 1 Km., strong cross currents and eddies are produced. A little below the islands a ridge of rocks appears on the left bank and advances obliquely for a considerable distance into the river. This ridge throws the current again towards the right bank where the water breaks upon the rocks with the greatest violence. These cross currents, confined and broken by the rocks, cause falls in which the water



N. Ivanoff—Pho.

O. I. Ignatieff, Art.-peintre.

L'Insatiable

(La Nenassytetski).

Entrée aval du canal inférieur et bateau-toueur d'expérience.

boils and surges with irresistible force. The most dangerous of these falls is named. *Hell* (fig. 29).

Fig. 29. — The Insatiable (Nenassytetski) Cape Monastyrko and Hell.

The combination of these different obtacles forms the Nenassytetski rapid, the total fall of which is from 4.810 to 5.203 m. (figs. 30, 31). The slightest deviation in a boats course or a sudden rise in the wind cannot fail to cause the loss of the craft.

By the side of this violent rapid, near the right bank, a canal has been constructed with two locks (§ 19). The length of this canal is 290 sagènes and its width is from 8 to 10 sagènes. The lock-chambers have a width ot 5 sagènes and a depth of 6 feet on the sills below the mean water level. This canal was very seldom employed. The smallness of the lock-chambers, the great loss of time in getting through the canal and the unfavourable position of its lower end have led to its abandonment (§ 19).

Subsequently another channel near the left bank was created in the Nenassytetski rapid with the help of open canals 745 sagènes long with dikes on each side (§ 22).

These canals have the same defects as those of the other rapids: the depth is insufficient and the entrance is difficult (§ 5).

Descending the Dnieper the Voronovaia *zabore*, with a fall of 2′ 2′′, is met with 6 versts from the Nenassytetski rapid, and 1 verst lower down is the Krivaia *zabore*.

There are a great many other *zabores* between the Nenassytetski and the following rapid, the Volnigski, so that navigation in this section is extremely difficult.

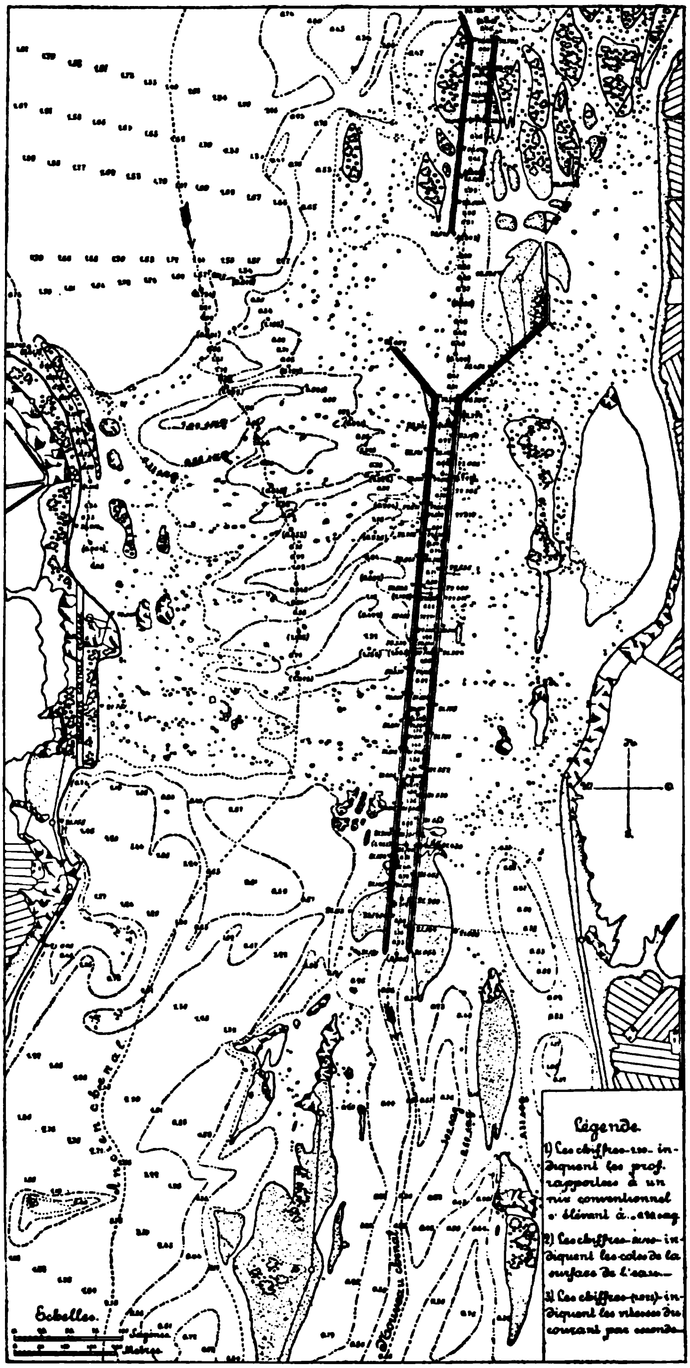


Fig. 30. — Projection of the Nenassytetski (Insatiable) rapid showing the works at present in existence.

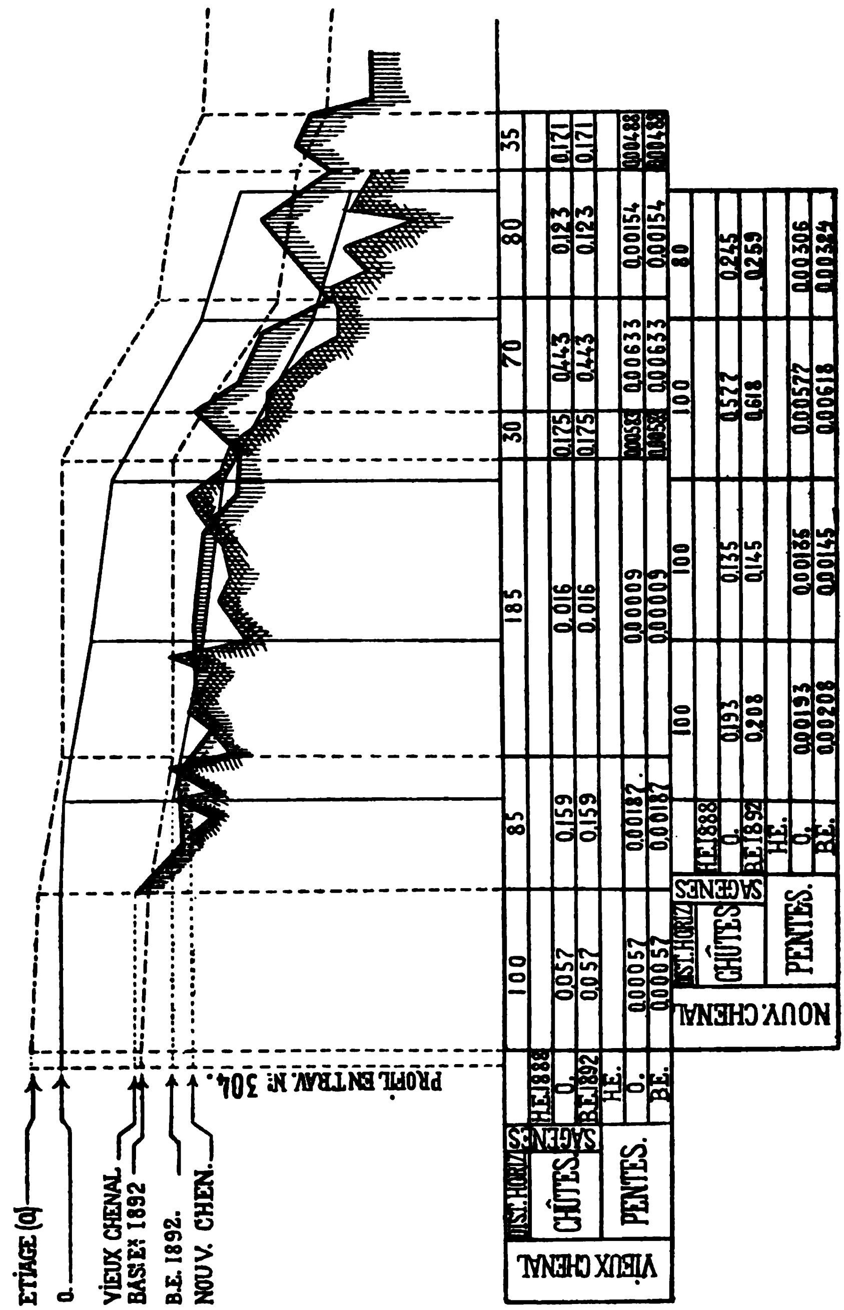


Fig. 31. — Longitudinal section of the Nenassytetski (Insatiable) rapid.

§ 12. The Volnigi.

Twelve versts 204 sagènes from the Nenassytetski rapid the river is again crossed by four almost parallel ridges which form the Volnigski rapid, the fall of which is between 1.903 and 3.314 m. The bed of the river is here only 200 sagènes wide, but a little further down stream the Dnieper increases both in width and depth.

From the foot of this rapid the two channels are separate until the next is reached.

§ 13. The Boudilov.

Five versts down stream the bed of the Dnieper is again contracted by rocks on both sides which leave it only a width of 200 sagènes. Two rows of islets 100 sagènes apart produce the Boudilovski rapid, the fall of which is 0.580 m. at low water. This rapid is not dangerous.

Two versts from here there are many islets, the principal of which are: Ossokorovaly, Tavaljany and Orlov.

In this region the river is more than one verst in width.

§ 14. The Superflue (Lishni).

About 16 Km. below the Boudilvoski rapid and above the island of Koukharev the bed of the river, confined by its banks of granite, is not more than 300 sagènes wide; but below this island it expands again to a great width. In this contracted space above the island detached rocks and collections of stones extend obliquely from the left to the right bank and form the Lishni rapid, the fall of which is 0.066 m. This rapid is the least dangerous for navigation.

§ 15. The Libre (Vilny).

The last large rapid, named the Vilny, is 4 versts 235 sagènes from the Lishni (fig. 32, 33). The channel passes between the islands of Lantoukhov and Gavine· The river-bed contracts visibly and finally is not more than 300 sagènes in width.

There are a large number of stony islands on the right bank. In this rapid, which is one verst in length, the old channel has a most irregular course. Near the right bank, at the foot of the rapid, three separate rocks stand up, between which there is a fair depth and a rapid current. The position of these rocks is such that a great many boats are drawn into this dangerous passage. Sometimes they are dashed to pieces, while at other times, if they do make their way through, they sustain such injuries that it is impossible for them to continue their journey. The name of Wolf's Saw has been given to the place. The Vilny rapid is regarded as one of the most dangerous.

The new channel in the Vilny rapid is guided by two dikes. The shallowness of this channel is its greatest defect.

§ 16. Pilots on the Dnieper.

The dangers with which navigation is attended in the diluvial section of the Dnieper gave rise in the sixteenth century to the formation of a corps of Cossak pilots who steered the boats and timber floats across the rapids. This corps of volunteers was under the superintendence of the Cossak Zaporogs. Towards the end of the eighteenth century, when the Zaporogs lost their independence and their capital (the Setch) was destroyed, the government did not cease to encourage the pilots on the rapids, but conferred upon them many privileges and rewards.

The villages of Lotsmanskaiakamenka and Kaïdaki upon the river-banks are to day free from all duties and taxes, even from military service, on condition that they devote themselves to pilotage.

In 1872 the total number of pilots on the rapids was 837. In 1892 it was 570.

These pilots, who are wonderfully skillful and plucky, are entirely depended upon for the navigation of the rapids, which without them would be impossible.

Still, even under their guidance, it is not always fortunate. Mishaps to boats and timber floats unfortunately frequently occur and sometimes there is a loss of human life. As insurance companies will not take the risk of insuring goods over the rapids, these accidents inflict severe losses upon trade.

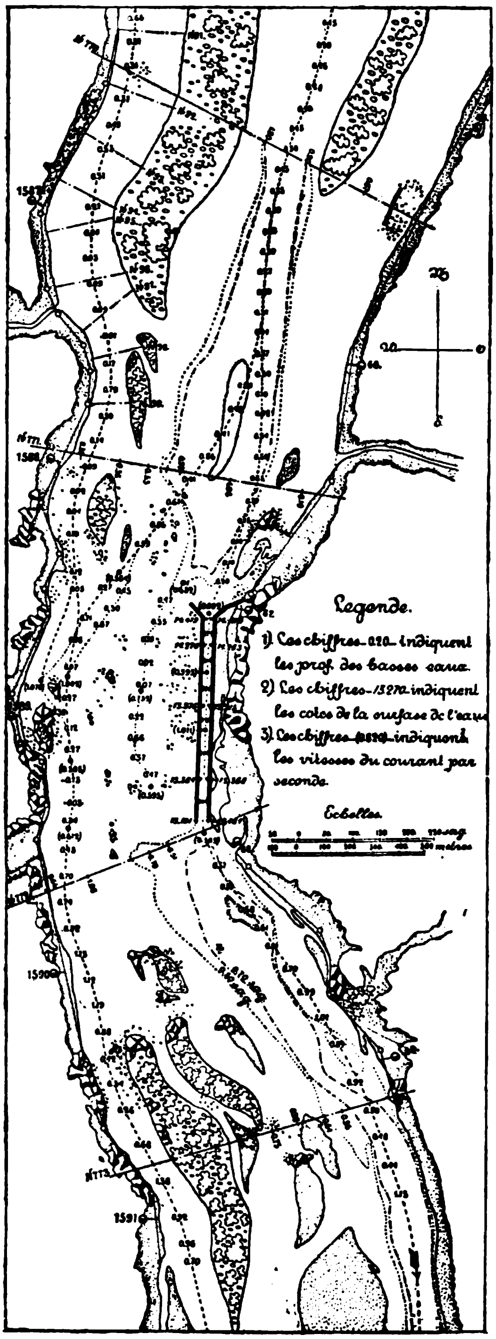


Fig. 32. — Projection of the Vilny rapid (Libre).

Fig. 33. — Longitudinal section of the Vilny rapid (Libre).

CHAPTER III.

Regulation of the rapids on the Dnieper, methods that have been adopted.

Contents: § 17. Introduction. — § 18. Works of the eighteenth century. — § 19. Works and schemes of General DE WOLLANT. — § 20. Schemes of the engineer CHICHOFF. — § 21. Experiments made in 1833—37. — § 22. Construction of open canals in the rapids on the Dnieper. — § 23. Latest schemes, studies and works (1855—93).

§ 17. Introduction.

The rapids on the Dnieper, which so seriously impede navigation on one of the most important waterways in Russia, have continually occupied the attention of the government since the annexation of the provinces which constitute New-Russia.

Numerous attempts have been made to improve the condition of the rapids with respect to navigation, but the works executed on various occasions with this object have not so far been able to realise any definite results with regard to the ascent, for the matter of expense has always stood in the way.

In briefly reviewing the principal works which have been executed for the regulation of these rapids we have no intention of merely going into a matter of history. These works taken together may in many ways serve as a technical lesson, for the conception of them, which dates back to last century, is founded on the principles which are followed nowadays in works of this kind, notably upon the Danube, the example of which will no doubt be followed upon the Dnieper.

§ 18. Works of the eighteenth century.

In the year 1771 Prince POTEMKINE, Governor-General of New-Russia, anxious to try every means for the development of the fleet and the new cities on the Black Sea, suggested the regulation of the rapids on the Dnieper. The works executed by Colonel FALEIEFF are mentioned in the description of a journey to Kherson in 1782 (1)

---

(1) ZOUEFF.

Among these works is included the canal in the Kodakski rapid as well as that in the Nenassytetski rapid, which stilll goes by the name of Faleieff's canal.

To judge from the latter they were small branch canals cut in the bank for the purpose of making a detour round the rapid.

These works are considered to be the first which have been undertaken on the rapids of the Dnieper. Nevertheless according to some authors it is to Peter the Great to whom the honour of the initiation of the first works for the regulation of the rapids with respect to navigation is due; but no trace of these works exists and only the tradition remains.

An impetus was given to the prosecution of these improvements by the journey of the Empress Catherine through the south of Russia. She paid a visit to the rapids in 1787 and established the corporation of pilots (§ 16), the members of which have since been exempt from taxation. By this act of generosity the Empress wished to glorify the courage and skill of the brave villagers, the inhabitants of Kaïdaki, who in her majesty's presence were able to steer the imperial flotilla over the Nenassytetski rapid, the most dangerous of them all.

§ 19. Works and schemes of General de Wollant.

In 1795 Colonel, and later General, de Wollant of the Engineers and Director-General of Ways and Communications (1812—18) was delegated by the imperial government to study the question of the rapids upon the spot. De Wollant's first idea was to make locks on all the rapids, but economy subsequently obliged him to modify his scheme. His next scheme was to adopt different methods according to the importance of the rapids, either a simple deepening of the navigable channel, or the erection of leading dams to prevent boats impelled by cross currents from leaving the channel, or the construction of locked canals. At first De Wollant's scheme included the construction of a lock for the Nenassytetski rapid only, while he proposed to regulate the others by more economical methods in the first instance and only to make locks when the requirements of navigation should render it necessary. The estimated cost of these works was only 1,136,000 roubles. General de Wollant's scheme was in 1797 honoured with imperial approval and the execution of it was commenced the same year. The work lasted until 1810.

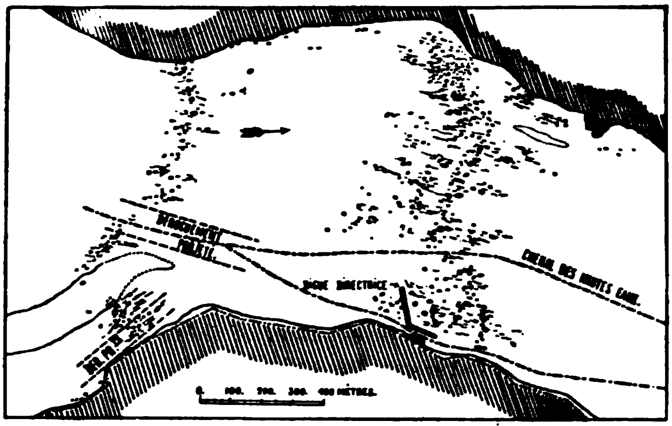


Fig. 34. Projection of the Old Kodak rapid showing the works executed according to the scheme of General de Wollant.

The principal operation was the deepening of the navigable channel. Leading dams which were built of unhewn stone were next constructed in the first three rapids, Starokodakski, Sourski and Lokhanski. The depth and width of these canals was small. The canal on the Old Kodak was hardly 20 m. wide (fig. 34).

The leading dams were also on a very small scale. That on the Old Kodak was only 50 sagènes in length, that on the Soera 80 sagènes and that on the third rapid, the Cuvette, 90 sagènes (fig. 35). The dams were very feeble and could not long withstand the effect of the ice and within a few years no trace of them was left.

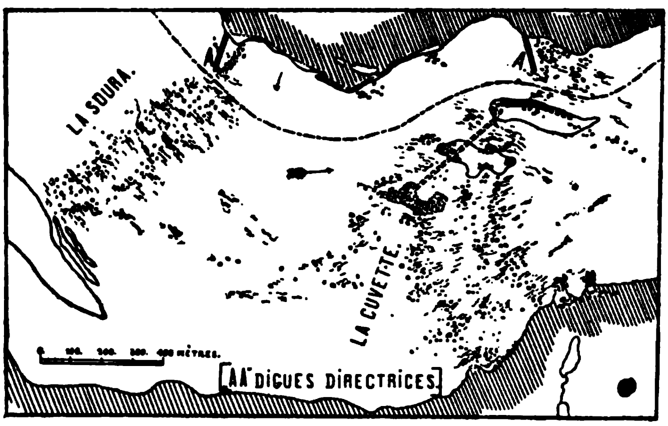


Fig. 35. — Projection of the Soura and Cuvette rapid showing the works executed according to the scheme of General de Wollant.

In the other rapids only the deepening of the channel was attempted and only in the Nenassytetski rapid was a canal made 105 sagènes in length having a lock with two lock-chambers and an intermediate basin, the total fall being 14 feet. The depth on the sills of these locks was 6 feet below a level which was considered the mean water level (figs. 36—41).

Fig. 36. — Projection of the Insatiable rapid shewing the works executed according to the scheme of General de Wollant.

The following is the manner in which as inspector of the work de Wollant described this lock in a letter addressed by him, under date of 2nd January 1805, to the Director of Ways and Communications.

„These two locks on the Nenassitetzky are constructed or hewn granite; „they are larger than the locks on the Ladoga-Canal. To get them into „position it has been necessary to cut a canal through a solid rock 55 „fathoms in length, 24 feet deep and 56 feet wide.

„It is well known that the Nenassitetzky rapid has baffled all methods „of improvement and that it only remained to construct the locks in „question in order to prevent the dessasters to which navigation is con- „tinually exposed in this rapid.

„All the other rapids, since their regulation and the fixing of the „direction of the navigable channel, are now passed without danger or

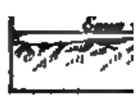


Fig. 37, 38, 39, 40, 41. — Projection and transverse section of the lock on the Insatiable executed according to the scheme of General de Wollant.

„loss; but on the Nenassytetzki there are always 5 or 6 craft lost in „the descent and as many timber floats, without counting the loss of „lives.

Fig. 42. — Present state of the lock constructed according to the scheme of General de Wollant in a lateral canal near the Nenassytetski (insatiable) rapid.

„There is no doubt therefore that it depends upon the construction of „these locks and other works in this region to obviate all danger in the „descent of the Dnieper over all the rapids during high and mean water, „and even in time of low water, if the level is not extraordinarily low. „In this latter case and for vessels to ascend the river — which the first „scheme provided for — there is no other method than to resort to the „construction of locks upon eight other rapids, for which those upon the „Nenassytetski when complete might serve as a guide and model."

The Nenassytetski lock was finished in 1808 and an experiment made with a boat proved the perfect working of the apparatus. By a decision of the 6th March 1808 the Emperor distributed rewards to the *personnel* directing the works.

Unfortunately this fine piece of work was of little or no utility for navigation.

The timber floats and boats which went down the Dnieper were larger in dimensions than the lock. Floats therefore had to be re-formed in order to pass through the lock and boats had to be lightened. Moreover the lock was difficult to approach on account of the shallowness of the channel leading to it. These inconveniences caused boats going down stream to pursue the old route.

With regard to navigation up stream, no use could be made of the

lock on the Nenassytetski on account of the other rapids, which could not be passed.

The lock was gradually abandoned and finally fell into decay; but it always remains a monument worthy of its author and a lesson, dearly bought it is true (the cost of it was $1^1/_2$ million roubles), of enterprises insufficiently studied from a financial point of view. If at the time when this lock was built the necessary funds had been available for completing the series, by making similar locks in the other rapids, we should to day find upon the Dnieper a navigation the activity of which would hardly be equalled in Europe.

§ 20. Schemes of the engineer Chichoff.

Ten years later the Direction General of Ways and Communications again took up the question. This time the engineer CHICHOFF was charged, in 1824, with the detailed study of the rapids on the Dnieper and the drawing up of a complete scheme for their regulation.

In 1826 the scheme was ready. It consisted in a detailed analysis of the solutions possible, such as the formation of a branch canal connecting the Dnieper above the rapids with the Black Sea or Sea of Azov, or of a lateral canal which would make a detour round the rapids, a locked canal in the bed of the river with dikes on each side throughout the diluvial section of the Dnieper, the removal of rock from the channel for ascending navigation with locks in each rapid, and finally open canals with dikes on each side, within the limits of each rapid, for navigation with the current.

With the locked canal in the bed of the river CHICHOFF calculated there would be 16 locks. The dikes required more than 5 million cubic metres of material. The estimated cost amounted to 10.643.014 roubles. Moreover CHICHOFF thought that constructive works placed in the bed of the river could not be sufficiently protected against the ice and that wind might render the canals inaccessible or difficult to approach.

A branch canal would according to CHICHOFF be free from these inconveniences. But after studying the different aspects of this solution CHICHOFF came to the conclusion that a lateral canal would require au enormous sum of money, for it would be necessary to cut the canal through hard rock rising often to a height of more than 35 sagènes or to lead it through a number of deep valleys.

CHICHOFF therefore regarded all these solutions as impracticable and adhered to the necessity of establishing two different and separate routes for navigation up and down stream. For the former be recommended between the rapids a channel 30 sagènes wide along the right bank, which should be formed by removing the rock for a depth of $5^1/_2$ feet below low water level, and locked canals on each rapid; for boats going down stream a channel 15 sagènes wide with a depth of $5^1/_2$ feet below

LA VOLNIGHI.
(LA VOLNIGSKI)
AVEC SON CANAL ET LE ROCHER „GROZA“.

low water (?) and with dikes on each side in the rapids. According to CHICHOFF the carrying out of this scheme would cost 4.200.000 roubles and would take 7 years.

It is remarkable that, although CHICHOFF proposed to build leading dams along his canals, he intended them to do no more than protect boats from the effects of wind from the side and he does not seem to have foreseen the much greater influence they would exercise on the distribution of the incline.

§ 21. Experiments made in 1833—1837.

The Direction General of Ways and communications only approved of part of CHICHOFF's scheme, viz-that part which dealt with navigation with the current. It was decided not to carry the scheme into immediate execution and it was agried to reserve the right of making certain modifications after an experimental study, which was judged to be indispensable.

A commencement was made with the dikes. At first it was thought that they should be done away with completely and that elastic supports which might protect boats from shocks under the action of the wind should take their place.

It was then proposed for the sake of economy to do away with one dike and to dig a second channel on the other side of the remaining dike, so that boats might find shelter from the wind on either side. Finally the sheme was reduced to an experiment upon the first rapid (the old Kodak).

Under this form the scheme obtained in 1833 the sanction of the Emperor, and the same year the execution of it was begun. This dike was built at a distance of 120 sagènes from the left bank of the river. It was composed of large blocks of stone, placed dry, and had a length of 150 sagènes, a height of about $12^1/_2$ feet and a width of 2 sagènes on the top (figs. 43—55). The channel was given a depth of 6 feet below low water level (?).

In the course of the work, from reasons of economy recognised by experience, it was agried to revert to the construction of two dikes one on each side of a single channel.

The second dike was only 9 feet high and 1 sagène wide at the top.

The work was finished in 1837. Five years later a portion of the left hand dike at the entrance to the canal was demolished in order to render the approach less difficult. At the same time this dike was raised to the height of that on the right hand.

The cost of this canal amounted to 89.427 roubles, but this sum increases to about 95.500 (fr. 238.750) if the previous works upon this rapid are included.

Experiments made in 1833—37. Regulation of the Old Kodak rapid.

Fig. 43—55.

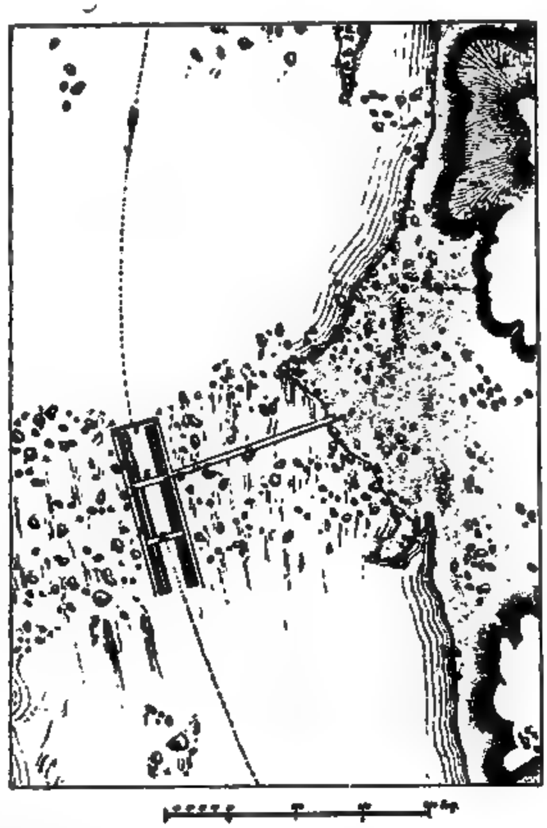


Fig. 43. — Projection of the diked canal.

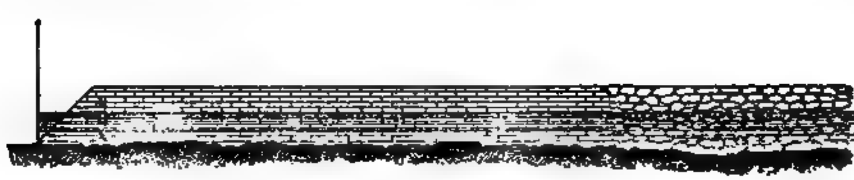


Fig. 44 und 45. — Elevation and projection of a dike.

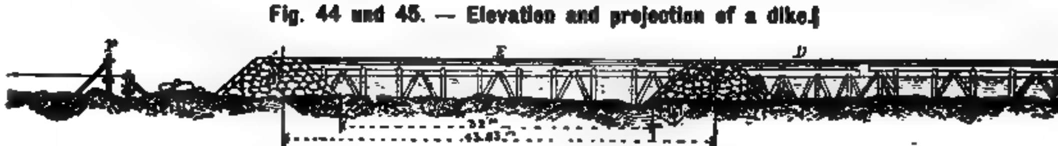


Fig. 46. — Transverse section of the canal.

Fig. 48.

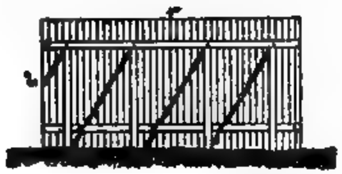


Fig. 50.

Fig. 49.

Fig. 51.

Fig. 54.

Fig. 52.

Fig. 55.

Fig. 53.

Fig. 47. — Transverse section of a dike through D E.
Figs. 48, 49. — Side view (from the river) and section of the cofferdam F F.
„ 50, 51. — Side view and section of the cofferdam G G.
„ 52, 53. — Projection and transverse section of the bridge.
„ 54. — Scales of figs. 49, 51 and 54.
„ 55. — „ „ „ 48, 50 and 52.

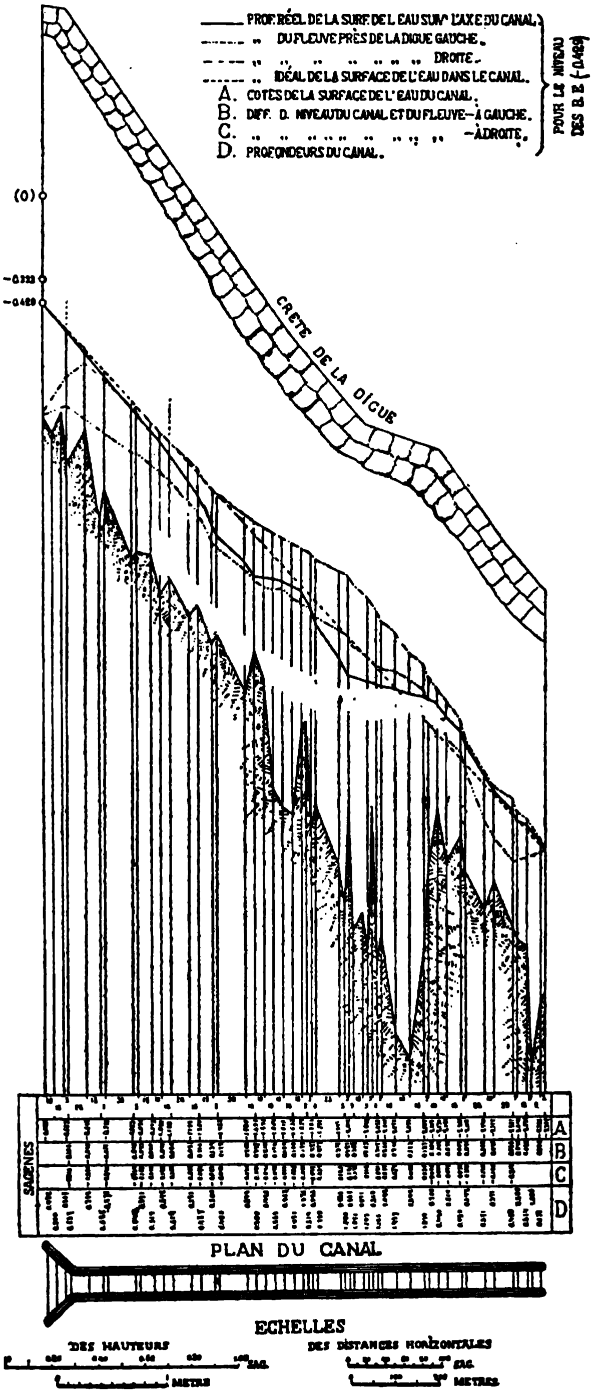


Fig. 56. — Longitudinal section and projection of the canal on the Insatiable, according to the observation of the engineer Regouiski (1858).

§ 22. Construction of open canals in the rapids on the Dnieper.

From 25 observations taken in 1842 in the canal of the Olk Kodak rapid it was found that the velocity of the current was 8 feet per second. This result appeared so favourable that it suggested the possibility of doing without locks for ascending the rapids on the Dnieper by hauling boats up, when necessary, by means of capstans fixed on the dikes of the open canals (1).

An experiment made with a boat confirmed the hypothesis.

This result helped greatly to accelerate the construction of canals in other rapids on the Dnieper (2).

For the canals in other rapids it was first proposed to establish a run at the entrance in order to facilitate the approach of the boats, but this idea was afterwards abandoned and the dikes were arranged as follows.

In the places where the width of the river is about equal to the normal width the distance between the dikes was to be diminished progressively towards the end of the canal. When the circumstances should be the reverse, it was proposed to diminish progressively the incline of the bottom, while preserving the same distance between the dikes throughout the length of the canal.

The scheme thus conceived was approved ot in 1843 and the same year a commencement was made to carry it into effect in the 8 succeeding rapids as well as in the reformation of the canal in the Old Kodak rapid.

This work was completed in 1854. The cost amounted to about 2,000,000 r., which sum includes the expenses of maintenance up to 1872.

The result of these works was to prolong the period during which navigation was possible with the current by one month.

The canals thus made in the rapids on the Dnieper, of which figs. 26, 27, 28, 30, 31, 33, 56 give a tolerably clear idea, were far from being quite finished. The inadequacy of the means available did not allow of giving the requisite width and depth, of removing the ridges in the channel between the rapids, of raising the dikes to a suitable height, etc.

The depth obtained was only 4 feet below low water level and in some places only $3^1/_2$ feet. The bottom of the canals was therefore visible in some places at times of lowest water. The dikes rose commonly 8 feet (2.4 m.) above low water level, while the high waters rose two or three times this height, even more. The canals could only be used for navigation during a limited period, when the average level was high enough to give a sufficient depth, and low enough not to overflow the dikes.

---

(1) The rapids on the Dnieper. Ann. des Voies de Com. 1845.

(2) Id. (observations of M. Golovatchef) A V C, 1863.

There were difficulties in the way of navigation against the current which were considered insurmountable.

Nevertheless the works of 1843—54 put in practice a principle which, nearly half a century later, found most weight in the choice of a solution for the Iron Gates on the Danube, viz. the adoption of open canals without locks.

§ 23. Latest schemes, studies and works (1855—93).

The comparative failure of the method of regulation with open canals in the rapids on the Dnieper, the causes of which were attributed to defect in the principle rather than to the manner of execution, caused locked canals again to come into favour.

Therefore in 1873 we hear of a new scheme for the regulation of the rapids, in which locks are considered as the only means for rendering this part of the river navigable against the current. This scheme, prepared by M. Mitrofanoff, engineer of Ways of Communication, unhappily since dead, provided for locked canals in all the rapids. Each canal was to be formed by means of a single leading dam at a short distance from the bank. The locks were placed at the lower end of the canal and were preceded by a weir, which was intended to keep the water in the canal at a fixed level. The number of locks provided for by this scheme was nine, three of which had two chambers and one a series of three chambers.

The dikes rose 0.20 sagène above the navigable water level and the sills of the locks were to be 5 feet (0.714 m.) below the conventional low water level (0) of the river.

The dimensions of the lock-chambers were $55^1/_2$ by 6 sagènes (118.4 $\times$ 12.8 m.). The side-walls were 0.25 sagène (0.533 m.) above the level of the highest floods (1845). The cost was estimated at 10,157,000 roubles (fr. 25,380,000).

The necessity of asking the treasury for such a sum frightened the Minister of Ways of Communication; the scheme was not approved of and the question was submitted to a series of fresh studies.

The question was again asked whether it was not possible to provide for navigation against the current without employing such costly works as locks, by making use of the canals already in existence. With this object a system of towing in the rapids was attempted. The experiment was not successful, both on account of the defects in the canals, which we have spoken of above (insufficient depth, irregular incline, etc.), and the defective means of towing. The failure therefore proved nothing, for there were instances of boats and even a dredger ascending the rapids; but the failure helped still further to discourage public opinion. It is to the personal influence of an eminent engineer, whose death is also much to be regretted, M. Golovatchef, director of Ways of Communication

in the district of Kiev, that the continuation of the studies and works on the rapids during this period of mistakes is due.

Strongly advocating the regulation of the rapids without locks, M. Golovatchef caused experiments to be made with the blasting of rocks below water by means of dynamite.

The work accomplished during the years 1884—86 were intended to give the old channel in the Old Kodak rapid a depth of 10 quarters of an archine (1.778 m.) below low water level with a width of 30 sagènes (64 m.).

It proved, on the one hand, the economy of using dynamite instead of powder, which had previously been employed, and, on the other hand, it disposed of a prejudice which greatly hindered the solution of the question and upon which we will say a few words.

The years of drought, which occurred after the construction of the canals in the diluvial section of the Dnieper, led people to believe that the removal of rock from the rapids was the cause of the lack of water in the river in the dry season. The hypothesis soon became a certainty, as far as the inhabitants in the neighbourhood of the river were concerned, and the report spread throughout the Empire, doing much harm to the cause of the ultimate regulation of the rapids. Numbers of people stated with the utmost assurance, although they had no knowledge of fluvial hydraulics, that the works on the rapids had lowered the level of the Dnieper as far as Kiev, several hundred kilometres from the rapids!

The works on the Old Kodak rapid proved *de visu* the absurdity of this statement.

The maximum lowering of the water level in the rapid, even below the excavation, was only 0.045 sagène (0.096 m.), and this could evidently only be observed near the rapid. Taking these experiments as a basis, M. Golovatchef with the help of M. Soulkovski, engineer of Ways of Communication formed a new scheme for the regulation of the rapids. This time there were to be two different ways, one for the descent and one for the ascent.

The first of these ways was to follow the old channel, all ridges of rock were to be lowered so as to give everywhere a depth of 10 quarters of an archine (1.778 m.) below low water level.

The second was to pass through canals with a depth of $7^1/_2$ quarters of an archine (1.335 m.) below low water level (0), and the dikes etc. of these canals were to be restored. The necessity of providing mechanical means of traction in the rapids was foreseen and only the ascent of empty boats was thought of.

The estimated cost was 1,600,000 roubles (fr. 4,000,000).

This scheme, presented to the Ministery of Ways of Communication in 1889, was not sanctioned like those previously drawn up, and, M. Golovatchef having died, it seemed that the rapids on the Dnieper

would be forgotten for long time, when the question was again taken up most energetically by His Excellency the Minister of Ways of Communication, M. A. C. Krivochéine, who gave it his attention almost from the time of his assumption of office (1892). Upon his visit to the ports and rivers of southern Russia M. Krivochéine was struck with the state of negligence of the diluvial section of the Dnieper, barring, as it did a hundred years ago, this water-course which offered such enormous possibilities to trade almost at the gate of the Black Sea.

A new study of the question was therefore decided upon in order to form a scheme for the complete regulation of the rapids. We have had the honour of being charged by His Excellency the Minister with the task, as flattering as it is difficult, of drawing up this scheme and of directing the experiments which are to furnish the basis of the system to be adopted.

In the following chapter we will explain the principles which we think must be followed in the investigations.

CHAPTER IV.

Principles of the scheme under consideration.

Contents: § 24. Comparison between the rapids on the Dnieper and those on the Danube. — § 25. Essential differences between the rapids on the Dnieper and those on the Danube. — § 26. Aim of the proposed regulation. — § 27. General discussion of the systems of regulation and the division of the rapids into categories. — § 28. Canals. — § 29. Projected locked passages. — § 30. Mechanical traction of boats and utilisation of the motive power of the rapids. — § 31. Experiments. — § 32. Conclusions.

§ 24. Comparison between the rapids on the Dnieper and those on the Danube.

In order to facilitate the examination of the principles upon which the regulation of the rapids on the Dnieper is based, we will commence this chapter by a succinct comparison between the characteristics of the diluvial section of the Dnieper with those of the diluvial section of the Danube, which the members of the present Congress are well acquainted with, thanks to the report presented by M. de Gonda to the Paris Congress in 1892. (1)

The Danube.	The Dnieper.
(a.) *Length of the diluvial section.*	
The length of the diluvial section of the Danube between the first rapid, Stenka, and the last, the Iron Gates, is 86 Km.	The length of the diluvial section of the Dnieper between the extreme rapids is 62.5 versts, or 66.7 Km.
(b.) *Total length of the sections obstructed by rock.*	
The total length of the places obstructed by rock in the diluvial section of the Danube is about 10 Km., or 12 $^0/_0$ of the entire length of this diluvial section.	On the Dnieper the combined length of the 9 rapids is equal to about 7 $^0/_0$ of the total length of the diluvial section. If the extent of the obstacles formed by the *zabores* etc. is added together, it would be found to compose not less than 20 $^0/_0$ of the diluvial section.

(1) We avail ourselves of this opportunity to express our thanks to M.M. Wallandt, Hoszpodski and De Gonda for the fund of informatiou they have been kind enough to give us with regard to the rapids on the Danube upon our visit to the remarkable works under their direction.

(c.) *Width of the bed.*

The width of the bed of the Danube in its diluvial section varies within the limits of 170 m. (the defile of Kazan) and 2020 m. (near Greben), or from 1 to 12.

The width of the bed of the Dnieper in its diluvial section varies much less, the extreme limits being in round numbers 400 to 1200 m., or from 1 to 3.

(d.) *Depth at low water.*

The depth at low water varies from 2 to 52 m., with the exception of five places, the rapids properly so called, where the depth becomes.

1.05	for the	Stenka	rapid.
1.8	„ „	Kozla-Doyka . .	„
0.2	„ „	Izlas-Tachtalia-Greben	„
0.7	„ „	Iucz	„
0.3	„ „	Iron Gates . . .	„

The periods of low water which give so little depth are exceptional and last only a short time.

According to the observations taken in a period of 40 consecutive years (1840—1880), during 158 days out of the 275, which is the average for navigation to be possible, the depth in the rapids on the Danube allowed of the navigation of boats drawing 1.5 m.

Besides the 9 principal rapids there are as many as 60 zabores, in which rocks upon the bottom or moveable stones reduce the depth, contract the channel etc.

The depth at low water is very small, falling to a few decimetres in a great many parts of the channel. Many stones in the channel emerge at this season.

When the water is not quite at its lowest level, 0.15 verschoks (0.67 m.), the descent even of timber floats becomes impossible.

(e.) *Total incline and average incline.*

The total incline of the Danube in the section between the extreme rapids is 23.392 m., which gives an average incline of 0.00027.

The total incline of the Dnieper between the extreme rapids, is 15.7 sagènes (33.44 m.), which gives an average incline of 0.0005.

(f.) *Maximum inclines.*

The inclines of the surface at low water on the Danube vary in the rapids from 0.0001 to 0.00417. The latter limit is only met with over a distance of 410 m. in the Iron Gates, where the average incline is 0.0032

The inclines of the surface at low water on the Dnieper are in many places much greater than the maximum upon the Danube.

Thus in the Cuvette the incline is 0.01064, in the Insatiable 0.0055, etc.

for one kilometre and 0.00199 for the entire length of the rapid (2.59 Km.), the total fall being 5.156 m.

(g.) *Maximum Velocity.*

The maximum velocity in the rapids on the Danube is found in the Iron Gates. It is hardly more than 5 m.

The maximum velocity in the rapids on the Dnieper is met with in the Cuvette, where it is 2.5 sagènes (5.33 m.) per second.

In the Insatiable it is 1.92 sagène (4.1 m.).

(h.) *Discharge.*

The discharge of the Danube according to the latest data is: at low water 1475 cub.m. and for a rise in the level of:

1 metre	2440	cub.m.
2 „	4000	„
3 „	5500	„
4 „	7700	„
5 „	?	„

The variations in the discharge of the Dnieper are much greater. The discharge calculated for low water is 29 cub. sagènes (282 cub.m).

At conventional low water the discharge becomes about 500 cub.m. At high water it rises to 9000 cub.m.

The maximum calculated for the highest floods is 17000 cub.m.

(k.) *Floods.*

The floods on the Danube rise 5 m. above low water level and in one place only (Greben) the difficulties of navigation increased on account of the falls and eddies which were here produced by a sudden widening in the bed.

The floods on the Dnieper cause the level to vary within the limits of more thau 8 m. According to the scale at Lotsmanskaia Kamenka the level rises to + 3.7 sagènes (7.9 m.) and sinks to — 0.60 sagène (1.28 m.).

As soon as the water level rises over 6 archines (4.27 m.) above low water level, the current, deviated by rocks, which emerge when the water is low, becomes so disturbed in many places that all navigation is forbidden by law in order that disasters may be avoided.

High water therefore on the Dnieper is attended with infinitely greater difficulties than on the Danube, the

conditions under which the river flows in the winter and summer beds differing greatly.

(l.) *Wind.*

Wind, always an inconvenience in a part of a river, where obstacles to navigation are met with, never causes a cessation of traffic in the diluvial section of the Danube. This is due both to the small number of rocks encountered and to the power of the engines of the steamboats.

Wind in the diluvial section of the Dnieper in its actual condition renders the descent of boats and floats absolutely impossible.

As they are carried along by the force of the current the crews cannot keep them in the channel if there is any side wind to speak of.

It is therefore often necessary to wait for days and weeks for favourable weather in order to pass the rapids.

Without this precaution there is great danger of disaster.

It should be remarked that, when a deep channel is created throughout the whole distance, the use of steam power will greatly diminish this inconvenience; but it can never completely disappear without the construction of far too costly works, on account of the enormous quantity of rocks scattered over this part of the river. It is not only in five places as on the Danube, but in dozens of places that a boat would run the risk of being injured if it left the channel under the influence of the wind.

(m.) *Navigation.*

The existence of the rapids on the Danube has not prevented navigation from developing to a remarkable extent upon this part of the river.

Numerous boats belonging to Austria-Hongary, Servia, Roumania and Russia ascend and descend the

The rapids on the Dnieper, in spite of the extensive works executed during the present century, do not admit of navigation with the current without risk; it is moreover only possible for some 75 days in the year. Against the current navigation

rapids. The draught of the boats may be 1.83 m., the engines of the steamers are of 400 horse power, and the capacity of the boats is 1.000 tons.

It is true that the rapids hinder navigation and even stop it temporarily, but out of the 275 days during which navigation is possible, on an average for 158. days boats drawing 1.50 m. are able to pass the rapids.

is impossible, only small craft being able to use the canals on the rapids.

(n.) *Regulation of the rapids necessary for navigation.*

Two metres at low water for all the rapids except the last, the Iron Gates, for which 3 m. is demanded.

Five feet (1.52 m.) at low water and the possibility of ascending the river with safety and economy.

§ 25. Essential differences between the rapids on the Danube and those on the Dnieper.

The comparative examination of the rapids on the Dnieper and those on the Danube leaves no doubt with regard to the relative difficulties which both present to navigation.

The fact noticed in the preceding paragraph, namely that there has been active navigation for centuries against the current on the Danube and that the same has been impossible in spite of extensive regulation works on the Dnieper, alone suffices to show that the latter in its diluvial section is a more powerful enemy than the Danube.

This conclusion is only too well confirmed by the results furnished by the above comparison.

It has been shown that:

the length of the section occupied by the rapids, rocks and obstacles in general is greater for the Dnieper than for the Danube (§ 24, *a*, *b*);

the depth at low water is much less in many places on the Dnieper than is met with in the shallowest places in the rapids on the Danube (*d*);

the total incline of the rapids on the Dnieper is nearly 50 % and

the average incline 100 % more than on the Danube (*e*);

the maximum incline of the rapids on the Dnieper is 150 % more than the maximum on the Danube (*f*);

the maximum velocity is in many places greater than the maximum on the Danube (*g*);

the variations in the discharge of the Dnieper (from 1 to 30 and even 60) are infinitely more considerable than on the Danube (*h*);

the floods on the Dnieper are nearly double of those on the Danube (*k*); and finally

winds render the passage of the rapids on the Dnieper most dangerous and frequently impossible, while on the Danube they are at the worst inconvenient.

There would therefore be a risk of falling into error if we proposed to apply to the Dnieper the system of regulation adopted for the rapids on the Danube without a scrupulous analysis of all the physical divergencies between the two rivers, as well as of the requirements of navigation in either case.

§ 26. Aim of the proposed regulation.

We have already said that at present the rapids on the Dnieper only allow of navigation with the current. Still this is only possible during a very short period and it is always dangerous. Five per cent of the total number of boats with their cargoes are lost every year. The boats, once they have descended the rapids cannot return to the ports from which they start. They can be used for only one journey, a circumstance which puts an enormous tax on goods. No serious improvement therefore in the construction of the boats is possible.

The regulation of the rapids therefore should do away with or diminish the causes which render the ascent impossible and the descent so dangerous for boats.

These causes are:

the sinuosity of the channel,

the insufficient depth,

the insufficient width,

the rapidity of the current and the abruptness of the inclines in the rapids,

the irregularity in the direction of the current, frequently oblique to the general direction of the channel,

the influence of winds.

With regard to the depth which should now be obtained on the rapids of the Dnieper, in order that navigation may be not only safe but economical in both directions, it is determined by the following considerations.

Boats from Berislav-Kakhovka, where the maritime portion of the Dnieper commences, should be able to ascend the river as far as Ekaterinoslav and farther; not only the boats which navigate to day upon the Lower Dnieper, but also those which will be able to navigate when the depth on the Lower Dnieper shall be 5 feet on the shoals, and it is hoped that this depth will be obtained.

It would also seem indispensable to increase the depth of the channel to 5 feet in the diluvial section between Ekaterinoslav and Alexandrovsk.

§ 27. General discussion of the systems of regulation and the division of the rapids into categories.

Various methods may be adopted for the creation of a channel sufficiently straight, wide and deep with a suitable incline and velocity of current.

N. Ivanoff-Pho. G. I. Ignatieff-Art.-peintre.

LA LIBRE.
(LA VILNY)
AVEC LA PASSE DE „GUEULE DE LOUP".

[illegible]

The universal method, which can always be adopted and which always gives certain and unquestionable results, is to build locks.

The most superficial observation however suffices to show that the adoption of this method for a river of the size of the Dnieper would require a most enormous outlay.

Moreover the adoption of such a method would not always be in keeping. The shoals of rock which form the rapids are in fact natural dams which divide the diluvial section into a number of reaches the depth of which is for the most part sufficient even at low water.

It would seem therefore that as the dam is already formed by nature it only remains for art to find the means of passing this dam from one reach to the other.

This may be effected either by a simple deepening of the channel over the rapid, or by means of a diked canal or by a lock.

There are several ways of adopting these different methods.

As we have seen upon the Dnieper itself the construction of locks, the cutting of canals and the removal of rocks from the bottom have been attempted.

In Sweden on the western branch of the Gotha canal, formed partly by the Gotha-Elf river, there are very considerable falls, which furnish an example of the adoption of locks on a large scale.

In America the branch canal of the rapids of Sault St Marie, on the St Marie river between lakes Superior and Huron, has a lock through which 10,000 boats pass every year.

Finally on the Danube, where the regulation of the rapids is still in the course of execution, it has not been thought possible to make use of locks. It has been sought to create a safe and deep channel by the direct removal of rock from the bed of the four upper rapids accompanied by a partial contraction of the bed and an open canal for the Iron Gates.

Which system is to be preferred for the future works upon the Dnieper?

We think all three must be admitted.

In our opinion in rapids with a slight fall and incline, when the principal defect lies in the insufficient depth in the channel, a very considerable improvement may be effected by a direct removal of rock from the bottom.

As was proved by the experiments made upon the Dnieper in the Old Kodak rapid (§ 21) in 1884—86, there is no occasion to fear that such an increase in the depth, if it extends over but a small portion of the width of the river, will be accompanied by any considerable lowering of the water level, either in the rapid or with less reason in the reach above.

It is hardly possible to fix an absolute limit of incline up to which only a deepening of the channel is necessary.

The following inclines are met with on the Danube:

in the Stenka rapid . . . . . $\frac{0.391}{1094} = 0.000357$ per M.

in the Kozla-Dojke rapid. . . . $\frac{1.699}{1721} = 0.00099$ „ „

in the Izlas-Tachtalia-Greben rapid $\frac{2.041}{1583} = 0.00129$ „ „

This limit is therefore about one in a thousand for the above rapids, especially if the last is not included, as the contraction of the bed by means of a dike complicates the situation.

We think also that it is undesirable to go much further. The observations taken with regard to the velocity of the current prove that in these conditions the maximum velocity is not more than 6 feet (1.83 m.) per second.

On the other hand it is shown by calculation that the incline of the diked canals should not be much more than one in a thousand for the limit of 6 feet which is not to be exceeded.

It would therefore be necessary to remove the rock directly from the bottom in the Lishni rapid and in the numerous *zabores* (ridges of rock with a slight incline).

However, the reach between the Nenassytetski and Volnigski rapids, where the *zabores* are close together and where the depth at low water is exceptionally small, appears to require a special study, in order to discover whether it might not be possible to reduce the expense which the removal of rock from the bottom of this section would entail by building either a locked dam or dikes to contract the river-bed like those of Greben and Jucz on the Danube.

To return to the remaining eight rapids (leaving the Lishni out of account), it remains to group them according to the two different solutions: locks and open canals.

If on the one hand the adoption of locks is a method which applies to every case, it is on the other hand excessively expensive and the cost is out of proportion to the importance of the fall.

With regard to open canals, if the Iron Gates may be taken as an example, it would seem that they can be adopted in rapids of any size. Thus in the Iron Gates a canal of this class regulates a rapid with a fall of 3.42 m. and an average incline of 0.00247. This however is only the case within certain limits. Too great a velocity is allowed in the canal or, in order that advantageous conditions may be established for navigation, the canal is made so large that the prime cost is increased.

It is therefore evident that the choice between a lock and a canal does not admit of a general solution.

It the fall is abrupt and violent, the lock, serving the same commercial movement, may cost much less than the canal.

For less considerable falls, especially if the rapid is long, the initial

expenses for the canal may on the contrary be considerably less than the cost of the lock.

The limits, within which each system is available, depend essentially on local circumstances, and these limits are extremely complex depending on the total fall and the length of the rapid, or on the average fall as well as on the cost of the items in the construction.

For the Dnieper this limit seems to be a fall of 2 m. and an average incline on the rapid of 2 mm. per metre.

Therefore the Nenassytetski, Volnigski and Vilny rapids, which each have a fall of more than 2 m. and an incline of more than 2 mm. per metre, should be regulated by means of locks.

The Sourski and Boudilovski rapids, which have a fall of less than 1 m. require on the other hand the creation of open canals.

Finally the two rapids Lokhauski and Zvonetski, having a fall more than 1 m. and less than 2 m., will be the subject of a comparative study in order that a decision may be arrived at.

This study should by no means be confined to the comparison of the cost of first establishment, but should also include considerations on the technical and commercial working expenses in the widest acceptation of these terms.

§ 28. Canals.

As we remarked in § 27, there are among the rapids on the Dnieper some whose fall is not more than 2 m. In these rapids it is evidently possible to make open canals, which would cost considerably less than locked canals and would furnish almost equal advantages to navigation.

The possibility of such a result was shown by commissions on the scheme for the regulation of the rapids on the Danube.

Thus for instance according to the scheme of the commission of 1874, the open canal in the Iron Gates rapid would only have cost about fr. 4,000,000, while the cost of a locked canal in the same rapid was estimated by the commission of 1879 at fr. 12,000,000 (1).

It is true that the commission of 1874 allowed of a velocity of as much as 4 m. and more per second in the canal, which would be impossible on the Dnieper; but on the other hand those who advocate canals point out that the comparatively rustic work of building an open canal with dikes on each side costs much less in Russia than abroad, where as with regard to the more delicate work necessary for locks the reverse is the case.

Besides the economical reasons with respect to the first establishment

(1) V. *Actenstücke zur Regulirung der Stromschnellen der Donau zwischen Moldova und Turn-Severin*, Wien, 1880, pp. 89, 124.

(2) Loc. cit. pp. 86, 87.

of canals in rapids with a medium fall, there are also many other reasons which make them preferable to locks. It is therefore evident that the maintenance and working of an open canal cost less than for a locked canal; that locks cause far more hindrance to navigation and do not admit of the same amount of traffic, especially when navigation down stream predominates, etc.

Finally there is another special reason for preferring canals to locks, a reason which only applies to the Dnieper, but which nevertheless merits our attention.

As the rapids still make navigation impossible against the current, many people think, as appeared at the last national inland navigation congress in Russia (held at St. Petersburg at the commencement of the present year) that, even after the disappearance of the main obstacles which the rapids offer, a shipping movement up stream of any importance, at least at first, cannot be depended upon.

For the first few years after the regulation, according to the opinion of the authorised representatives of the navigation on the Dnieper, no other navigation up stream cau be expected except empty boats, such as are at present broken up after their arrival at their destination.

If therefore, these critics affirm, it is proposed to effect from the commencement a complete regulation of the rapids in question, it will be necessary to run the risk of laying out a sum of money out of proportion to the utility immediately realised. The government might thus overreach the end in view, which should at first meet simply the actual requirements without burdening the budget with expenses which could only serve for the distant future.

It this view of the case is admitted, another argument in favour of open canals is added.

An open canal admits of a certain elasticity with regard to the expenses it entails. Being appropriate only to actual requirements it can be enlarged subsequently in proportion to the development of navigation. The dikes of an open canal can be lengthened or raised, the incline may be reduced and the depth increased. As much may be said of the width, even when the bank of the river takes the place of a second dike. Moreover nothing prevents of locks being subsequently added, if the need of it is felt.

Canals thus allow of the distribution over a certain length of time of the outlay necessary for the regulation of the rapids on the Dnieper.

All these reasons demand the study of the requisite conditions for open canals in some of the rapids on the Dnieper (1).

The canals will be cut in the riverbed itself.

---

(1) The canals in the rapids have been stüdied by us in collaboration with M.M. Kandiba, engineer of Ways of communication, and Packievicz, Anc. E. Ec. P. Ch.

They should be near the bank which allows of the length of the dike being as small as possible and the incline as uniform as possible throughout the length of the canal.

The advantages realised by this arrangement, in comparison with the system of placing the canal in the middle of the river, have been confirmed by the commissions which were charged at different times to study the scheme for the regulation of the rapids on the Dnieper.

Thus the commission of 1874 remarked with reason „that it would not „be impossible to make a diked channel in the central part of the river, „but it would be much more difficult and expensive than near the banks; „moreover the two dikes in the middle of the river would cause great „confusion at times of high water". (1) The commission of 1879 confirms this opinion and adds that „the canal in the middle of the river would „not regulate the bed of the low waters. It would in fact meet with „either high ridges or deep hollows. The lowering of one ridge would „only carry the fall to the ridge above and a considerable quantity of „rock would have to be removed on the upper falls. We will not insist „on this point, for all agree that a channel in the centre of the „Danube should not be adopted."

Whereover the surface of the river or the natural formation of the banks do not admit of the dike along the bank being completely done away with, it might perhaps be built only for a certain distance, at the beginning and end of the canal. In this way a partial increase in width might be allowed in the intermediate portions of the canals, an increase which in certain circumstances might be more useful than otherwise to navigation. In fact an increase in width for a short distance, followed by a contraction, may be accompanied by a rise in the level; (2) also the velocity of the current being in inverse ratio to the area of the transverse section, with respect to a constant discharge, and the resistance which boats offer to traction decreasing in proportion to the increase in the transverse section of the canal, a partial increase in width would facilitate traction, serve as a siding or passing station, etc.

As to the velocity of the current, it should not be more than about 6 feet, or 1.83 m., per second, and it is proposed in the future to reduce it as far as possible.

The length of the canals should at least be such that the mean incline is not much over 0.001 per metre a figure we are inclined to consider as the maximum limit for navigable rivers. (3) But provisionally, perhaps,

---

(1) Actenstücke zur Regulirung der Stromschnellen der Donau zwischen Moldova und Turn-Severin, Wien, 1880, p. 85.

(2) See f. i. *Cours d'hydraulique* by M. Flamaut. p. 273.

(3) Elie de Beaumont, *Leçons d'hydraulique, torrents, rivières, fleuves, vallées,* Cours professié au Collège de France. Paris, 1869.

more pronounced inclines will be tried, without probably adopting an incline of more than 0.002 per metre, which is more or less the limit between torrents and rivers (1).

As regards the depth in the passages over the rapids on the Dnieper, it is thought that for the present not more than 5 feet (English), or 1.524 m., below the low water level of 1892 can be obtained, for it would be impossible to realise at once a greater depth between the rapids without an excessive outlay.

This depth moreover depends upon the state of the Dnieper below Alexandrowsk, as we pointed out in § 26.

The width of the canals is determined by the following considerations.

To give greater freedom of movement to boats, as well as greater facility to traction, there would be some advantage in increasing the width of the canals (2).

But on the other hand with the increase in the width, the velocity and especially the volume of water necessary to feed the canal, also increases, although these elements increase more particularly with the depth, while the width. as is well known, has less influence.

As we have already seen, the greater number of the canals made in the rapids on the Dnieper (§ 22) between 1843 and 1854 for the descent, have a width of 15 sagènes (32 m.) on the bottom. This width is very small, as among the boats which navigate the Dnieper there are some which have a breadth of beam of 9 sagènes (19.2 m.). Although the number of boats having this exceptional width is very limited, the width of 15 sagènes at the bottom is considered insufficient and there is a general tendency to admit a greater width for the canals intended for the use of navigation against the current.

In the canals through the Iron Gates on the Danube a width on the bottom of 80 m. (about 38 sagènes) was admitted, with a depth of 2 m. below low water level (3).

Such dimensions can not be adopted on the Dnieper.

With a width on the bottom of 15 sagènes, a depth of 5 feet and an incline in the bed of 0.001, a velocity of 0.93 sagènes, or about 2 m. and a discharge of about 16 cubic sagènes (155 cub. m.) would be obtained.

This discharge is relatively great, since the total discharge of the river at low water is only about 30 sagènes. But there is reason to believe that the actual discharge would be much less than what we have indicated.

---

(1) See Bazin, *Recherches hydrauliques*.

(2) See Du Buat, *Principes d'hydraulique*, 3rd part.

(3) Bella de Gonda. *Les Cataractes du Danube*. Paris, 1892. — The depth has since been increased to 3 m., which has reduced the width on the bottom.

In fact to find this discharge, the coefficient c in the formnla

$$v = c\sqrt{Ri}$$

was calculated according to the formula of Ganguillet and Kutter by taking for the coefficient of friction $n = 0.02$, a value which has reference to walls of rough unhewn stones.

The numerous observations taken on the canals on the Dnieper prove that the actual velocity is much less than it ought to be if the above formulae and the coefficients correspond to the state of the case. A series of calculations made for the canal in the Insatiable and Libre rapids seems to prove that the coefficient c in the formula.

$$v = c\sqrt{R\,i}$$

is about 20 for measurements in sagènes and 39 for measurements in metres, while its value for $n = 0.02$, according to the formula of Gan guillet and Kutter, would be 37 for measurements in sagènes and 54 for measurements in metres.

The discharges of the canals destined for ascending navigation therefore will be unquestionably less than the calculations indicate. If it is observed also that the state of low water, for which the proportion seemed unfavourable, is quite exceptionable and that with the average depth the discharge of the Dnieper is about 50.3 sagènes, it will be evident that the creation of canals 20 sagènes (42.6 m.) wide on the bottom with au incline of 0.001 per metre is quite possible.

At high water the velocity of the current will naturally be much greater, as the following formula indicates approximately:

$$v = a\sqrt{h\,i}$$

or

$$v = b\sqrt[5]{Q\,i^2}$$

If k represents the ratio between the discharges at high and low water, m the ratio between the mean inclines and α the ratio between the variations in velocity in the same states of the river, it is easy to see that

$$\alpha = \sqrt[5]{km.}$$

For the Dnieper we may put $k = 30$ (§ 2); m varies within very wide limits, from 1 to 10, for the different rapids (§ 6). Putting $m = 1$, we have for this case, the most unfavourable,

$$\alpha = 2.02.$$

It will always be possible to keep within this maximum, for it can be arranged so that the discharge of the canal shall increase less in proportion to the quantity of water in the river.

The dikes shaull be composed of the stone removed from the channel. They shall have a width at the top of 1 to 2 sagènes (about 2.10 to 4.20 m.); the talus shall have a height of 1 m. for each metre of base.

With regard to the height of the dikes, it would be difficult to fix it absolutely. Dikes that are too low will only have a limited influence on the distribution of the incline and the moderation of the velocity when the water is high. But the extent of the variation in the level of the Dnieper is more than 9 m. The dikes would therefore have a very fair height if they were raised above the high water level.

This level however is exceptional, and the floods on the Dnieper, which only occur once a year, in the month of April, last for a very short time.

These data therefore are sufficient, after making a series of observations, to fix a height for the dikes which it would be of little use to exceed.

§ 29. Projected locked passages.

In the rapids which have a considerable fall and would require canals more than 1 or 2 km. in length, and especially if the fall is concentrated and the rapid is of limited extent, a locked canal may be more economical than an open canal.

In these conditions are included the creation of locked passages, the principles of which we will here briefly explain (1). The locked passages will be near the bank the approach to which is most easy and the locks will as far as possible be placed below the rapid, in order to reduce the work of excavation, which is very expensive in consequence of the extremely rocky nature of the bed. Instead of building two leading dams one on either side of the locked canals, which is the usual thing to do, only one will be built wherever local circumstances will allow of it and the neighbouring bank can take the place of the other dike. In this manner a certain economy may be realised which promises often to be very considerable, thanks to the form of the banks which in most cases is favourable.

By this arrangement other advantages will be obtained which will be treated of later.

Generally it is sought to avoid all current in the lock-chambers as well as in the canals approaching them, except such as are inevitably produced each time they are opened. But in the special case which occupies us, the absolute absence of current in the canal approaching the lock might cause some inconvenience. The current of the river, which becomes stronger as the rapid is approached, being unable to pass through the canal must necessarily turn away from the entrance, which the boat might fail to fetch and thus be lost in the rapid, the more easily the more oblique the current is to the entrance of the canal.

---

(1) We have stndied the locked passages in collaboration with M. P. Bérésine, engineer of Ways of Communication.

In order to avoid this inconvenience it would be desirable to allow a certain amount of current in the canal leading to the lock.

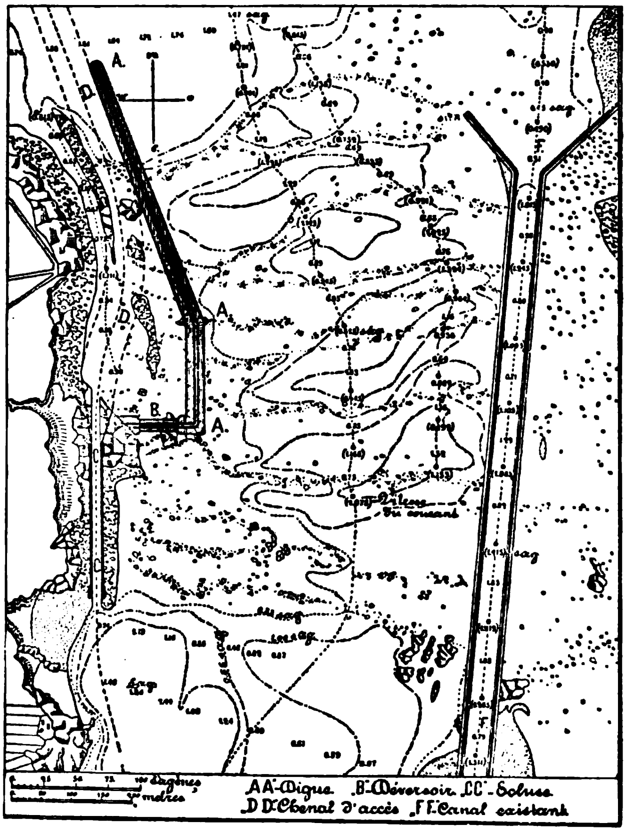


Fig. 57. — Projection of the proposed works for the passage of the Insablable.

We therefore propose to build in the canal above the lock a weir B which will give a certain discharge corresponding to the discharge at the entrance to the canal leading to the lock (fig. 57).

In order to be able to regulate this discharge according to the variations in the level of the water, the width of the weir may be varied by means of movable shuttings. The discharge will thus be regulated so that at the entrance to the canal leading to the lock there will be no eddy capable of causing a cross current, but there will on the contrary be a current sufficiently strong (without however causing inconvenience) to facilitate the movements of boats entering the canal.

When navigation ceases, the weir may be completely closed, so that there may be no current when the ice breaks up; the ice is thus prevented from entering the canal and the protection of the works is secured.

It is evident from what has been said that the dike, which with the bank forms the canal leading to the lock, need only be water-tight if it is certain that the filtrations will not be greater than the charge available for feeding the canal. As there is no certainty of this we propose to make the dikes water-tight. As regards the position of these dikes, it is to be remarked that they will not be parallel to the bank. We prefer that the dike should make a certain angle with the latter so that the canal leading to the lock gradually widens out in a down stream direction. By this arrangement it is intended to gradually diminish the velocity of the current in the canal and thus to reduce to a minimum the inconvenience which this velocity might present to navigation in a locked canal.

The locks will be able to receive boats whatever the condition of the water may be. The filling and emptying of them will be assured by means of aqueducts in the side walls which communicate with the lock chamber by a series of openings along the bottom. The advantages of this mode of filling are too well known for it to be necessary to dwell upon it here. We will only remark that to obviate as far as possible the action of the water on the hulls of the boats, which are often very lightly built, we have thought it desirable to place the apertures much lower than is usual and to increase the number of them rather than to make them too large.

The sills will be of a depth of 8 feet (2.44 m.) below the water level of 1892. It is greater than the depth to which it is proposed to increase the navigable channel in the near future. But in projecting works of such a costly nature is it not essential to take into account the requirements of a more distant future?

The other dimensions of the locks have been fixed in accordance with the dimensions of the boats which navigate the Dnieper and the navigable passages in the bridge of Kiev.

The length of the lock-chamber is 90 sagènes (192 m.); it can consequently receive a train composed of three of the longest boats that are met with on the Dnieper.

A greater length in the chambers could only be useful in certain cases, while on the other hand if would rather tend to hinder navigation as it would increase the time necessary for filling in ordinary cases.

The width of the lock-chambers will be 7 sagènes (14.94 m.)

The gates for closing the locks will have only one leaf. We have adopted this arrangement, because it presents several advantages over the use of mitred lock gates. They are more simply and more easily handled, they exercise no pressure on the side-walls and the forces are distributed over them more regularly. The greater the opening and more considerable the forces to be withstood, the more pronounced are these advantages.

The opening as well as the closing of the leaf will be effected by

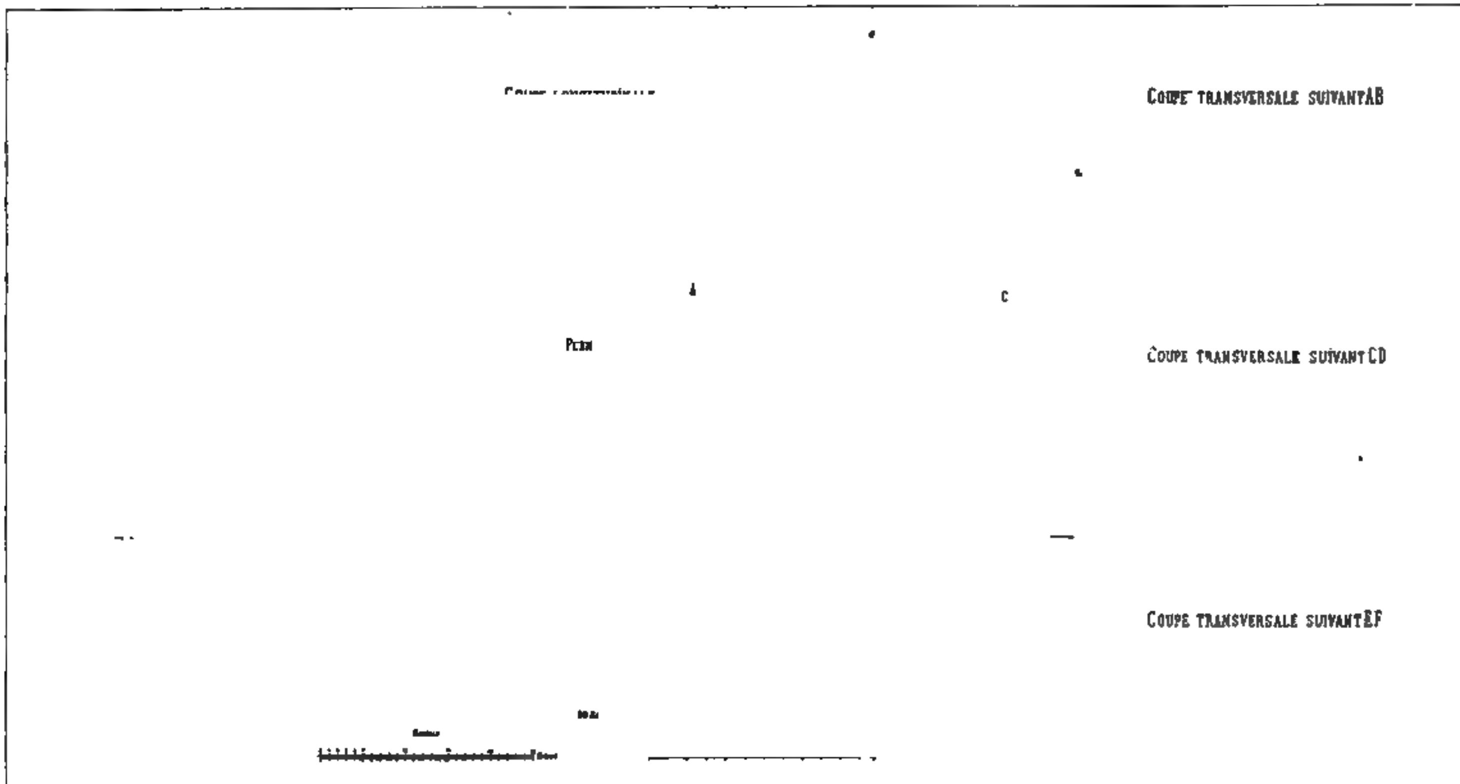
rotation round a vertical heel-post. This arrangement is better adopted to the circumstances than any other.

The working of the gates, as well as the traction of the boats at their entrance to and exit from the lock-chamber, will be managed by means of suitable apparatus which will be moved by the motive power of the fall.

To complete this sketch of the arrangements adopted for the locked passages, we have to add that we endeavour to utilise as far as possible the works already in existence, while it is sought to leave the old naturally navigable channel intact.

Thus for the Insatiable we have arranged to build the lock on the site of the old lock of General DE WOLLANT, making use of the excavation already effected.

With regard to the details of the arrangements adopted, they are made sufficiently clear by the sketches of the plan drawn up by us for the new lock on the Insatiable. (figs. 58—64).



Figs. 58, 59, 60, 61, 62. — Plan of a lock for the Nenassytetski (Insatiable) rapid.

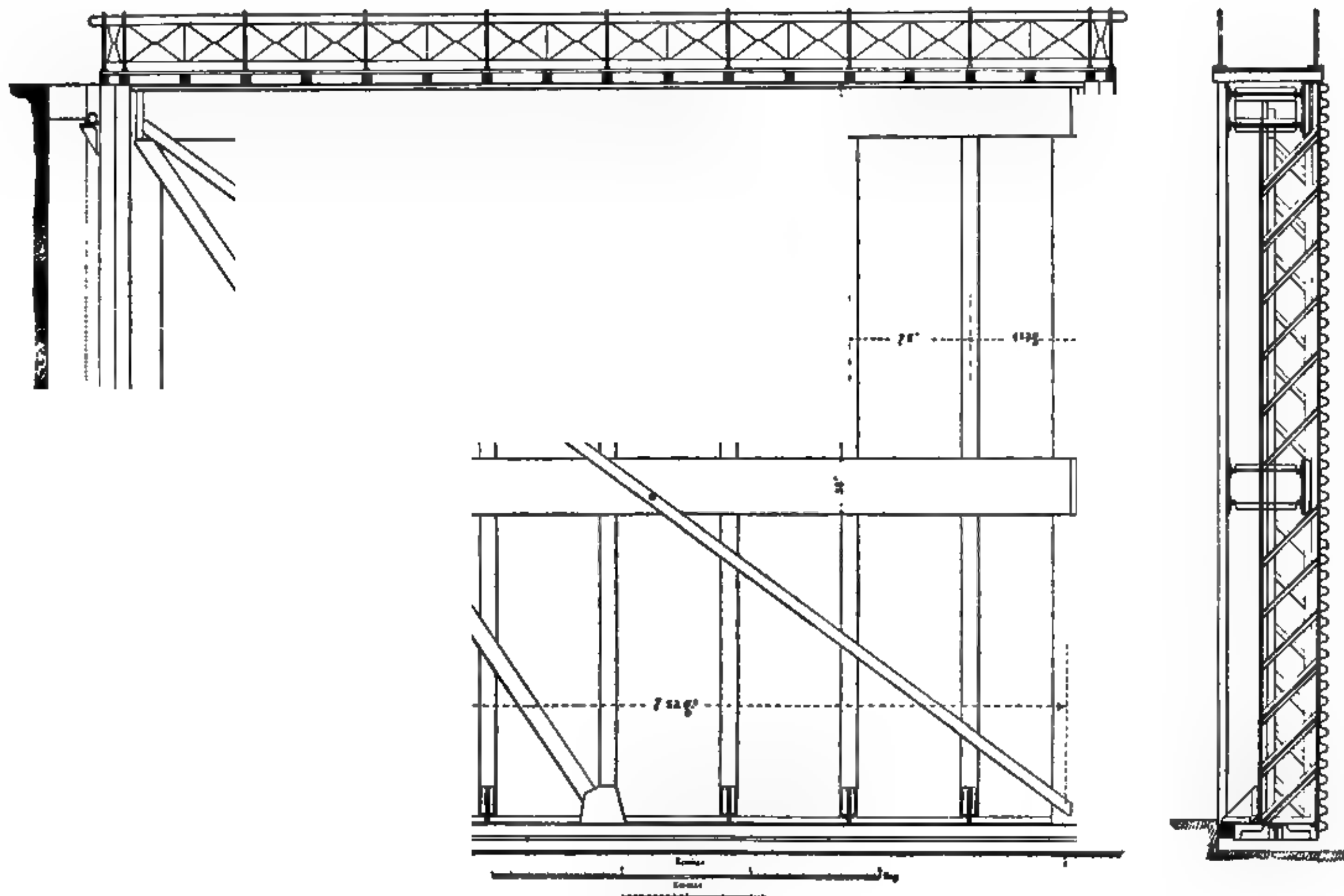


Fig. 63, 64. — Plan of a one leafed gate for the lock on the Issabiable.

§ 30. Mechanical traction of boats and utilisation of the motive power of the rapids.

No method of regulating the navigable channel in the diluvial section of the Dnieper would ensure complete safety for navigation during a cross wind, such a wind by driving the boat against the rocky talus of the channel might be the cause of disaster.

It is true that a deep and wide channel is certainly a considerable guarantee in this respect, both in consequence of the protection afforded to the boat and on account of the possibility of giving the motors a sufficient power to struggle against the effects of the winds.

It seems to us however that a warping cable placed in the channel would be a useful precaution, not to speak of the possible economy to be derived from the use of a regular warping apparatus throughout the diluvial section, both with respect to the working of this section and the cost of first establishment.

It goes without saying that the motive power of the falls formed by the rapids should be utilised as far as possible for warping, towing, lighting, etc. The transmission of power by means of electricity would here be of the greatest service.

§ 31. Experiments.

Since the regulation of the diluvial section of the Dnieper necessitates the extraction of a large quantity of rocks in an excavation of comparatively little length, the exact determination of the net cost presents considerable difficulties.

Although the works that have been carried out might furnish many elements which would throw light upon the situation, the Minister of Ways of Communication thought it prudent, before making any definite estimate, to do some work by way of experiment on a sufficiently large scale to obtain the necessary information.

The last rapid, the Libre, was chosen as a field of operation.

The trial works form an integral part of the works projected for the regulation of this rapid.

The scheme elaborated for the Libre consists in making a locked canal with a minimum depth of 5 Englisch feet (1.524 m.).

The site of the canal is chosen so as to use as far as possible the old canal which is cut through the rapid and is 380 sagènes (811 m.) in length.

The trial excavations in the rock will be partly excecuted in this canal. In this manner not only a part of the works of the future locked canal will be completed from the commencement, but with a comparatively small outlay a sufficient regulation of the Libre will be effected to faci-

LE DÉFILÉ DE „SHKOLA".

EN AMONT DE KITCHKAS

À LA SORTIE DE LA PARTIE TORRENTIELLE.

[illegible]

litate the passage of this rapid for descending navigation, which at present encounters serious difficulties.

According to the decisions taken by the Technical Council of the Minister of Ways of Communication it seems that this result may be realised, if the entrance to the canal is widened and lengthened in an up stream direction and the bottom is dug 0.8 sagène (1.71 m.) below the conventional low water level.

The lengthening of the dikes will be effected with the help of the stone taken from the excavation and this will only admit of giving to the dikes a height of 1.16 m. above the conventional low water level.

In order to study the net cost of the removal of rock that it is necessary to effect between the rapids and in a general way outside the dikes it is proposed to deepen the channel below the Libre in such a manner as to regulate the present passages as far as possible.

The trial works consist in the extraction of something like 20,000 cub. m. of rock.

§ 32. Conclusions.

Recapitulating the preceding considerations and confining ourselves to general conclusions we think that it is proved that:

1. The establishment of a safe and economical navigation in the rapids on the Dnieper, both with and against the current, is a necessity for the country.

2. The regulation of the rapids on the Dnieper by means of works in the riverbed itself is perfectly possible without the necessary outlay being out of proportion to the sums expended on similar enterprises elsewhere or to the advantages which will result with respect to the industry and commerce of the country.

3. The system of regulation which seems most suitable to the rapids on the Dnieper is a mixed system comprising the removal of rock from the bottom, the creation of open canals and of locked passages, each of these metods of regulation to be adopted by preference according to the importance of the fall and the length of the rapid.

4. The establishment of a mechanical system of traction throughout the section of the rapids would not only facilitate the working of the section but would also diminish the relative importance of the fall and the length of the rapid and would allow of the width of the channel being reduced.

5. The using of the fall for the traction of boats, working of lock gates, lighting, etc., and the transmission power by electricity appears to be desirable, whatever the system of regulation of the rapids may be.

It would hardly be possible to conclnde this report without doing hommage to the memory of the eminent Dutch engineer whose name is placed on the first page.

Called upon to do service in Russia in 1787, FRANCIS DE WOLLANT, who had the rank of captain of engineers in the Dutch army, had in the first instance a brilliant military career in Russia. He took part in the wars with Sweden (1788) and Turkey (1789), built fortifications in the south of Russia and in (1797) already had the rank of major general. During this first period of his service in Russia, DE WOLLANT distinguished himself as a very clever engineer, not only with regard to military operations, but also in works which were necessary for the development of pacific communications. He took an active part in the works of some towns in the south of Russia, the construction of the port of Odessa, the study of the Dnieper and the Dnester. Becoming ill in 1797 he retired from the army, but was almost immediately nominated a member of the Department of Ways of Communication. It is thus that he became specially attached to the development of ways and communications with regard to which he rendered the greatest services and obtained the highest honours.

During this second period of his service a part of the works which he had devised for the Dnieper in 1796 were executed.

The scheme which DE WOLLANT had conceived may still, after a century, be of the greatest service to whoever is called upon to continue the unfinished work for the regulation of the rapids on the Dnieper.

And we are extremely happy to take such useful lesson from the work of an enginecr belonging to the noble Dutch nation, which formerly offered its hospitality to one of the greatest monarchs, who studied in Holland the art of building canals and ships, to the nation, which today so graciously receives the representatives of the navigation of all countries.

Inscriptions des Planches.

FIG. 2 ET 3.

Navigation.
Amplitude maximum.

FIG. 4.

Courbe des débits.

Axe des niveaux du fleuve.
Le zéro de l'échelle d'Ekatérinoslaw est à 0,397 sagènes au-dessous de l'axe des débits.

FIG. 5—20.

Coupe longitudinale.
Vue latérale.
Coupe transversale.
Toitures transversale et longitudinale.

FIG. 21.

Nombre de bateaux, radeaux.
Totaux.
Moyennes annuelles.

FIG. 24 ET 25.

Pentes.
Cotes des H. E.
Cotes du fond.
Distances horizontales.
Niveau conventionnel.

Verstes comptés de . . .
Echelle.
Longueur.
Hauteur.
Les profondeurs sont exprimées en sagènes.

FIG. 26.

Les chiffres — 2,90 indiquent les profondeurs rapportées à un niveau conventionnel s'élevant à + 0,18 S.

Inschriften der Zeichnungen.

FIG. 2 UND 3.

Schifffahrt.
Höchster Wasserstand.

FIG. 4.

Kurve der Wasserabfuhr.

Achse des Wasserspiegels.
Null am Pegel von Jekaterinoslaw liegt 0,397 Saschene unter der Achse der Wasserabfuhr.

FIG. 5—20.

Längendurchschnitt.
Seitenansicht.
Querschnitt.
Längen- und Quer-Ansichten des Verdeckes.

FIG. 21.

Anzahl der Boote, Flösse.
Zusammen.
Jahresdurchschnitt.

FIG. 24 UND 25.

Gefälle.
Hochwässerstände.
Bodenerhebungen und Vertiefungen.
Wagerechte Entfernungen.
Den Berechnungen zu Grunde gelegter Wasserspiegel.

Werst von . . . .
Maasstab.
Länge.
Höhe.
Die Tiefen sind in Saschenen angegeben.

FIG. 26.

Die Ziffern — 2,90 bezeichnen die auf einen bestimmten Normalwasserspiegel (+ 0,18 Sasch.) bezogenen Tiefen.

Description of the Plates.

FIG. 2 AND 3.

Navigation.
Highest water.

FIG. 4.

Curve of the variations in the discharge.
Axis of the water level.
The zero of the Ekaterinoslaw scale is 0.397 sagènes below the axis of variations in the discharge.

FIG. 5—20.

Longitudinal section.
Side view.
Transverse section.
Longitudinal and side view of the deck.

FIG. 21.

Number of boats, floats.
Total.
Average in the year.

FIG. 24 AND 25.

Incline.
High water-levels.
Bottom-levels.
Horizontal distances.
Standard water-level.

Verstes from . . . .
Scale.
Length.
Height.
The depth is calculated in sagènes.

FIG. 26.

The figures — 2.90 indicate the depth compared to a conventional level of + 0.18 sagènes.

Les chiffres — **27,140** indiquent les cotes de la surface de l'eau.

Les chiffres $\boxed{1{,}025}$ indiquent les vitesses du courant par seconde.

FIG. 27.

Hautes eaux.
Profil en trav.
Etiage.
Basses eaux.
Nouveaux chenal.
Vieux chenal.
Chutes.

FIG. 28 ET 30—33.

Voir les traductions sous Fig. 26 et 27.

FIG. 34 ET 35.

Derochement projeté.
Chenal des hautes eaux.
Digue directrice.
Dernier projet.

FIG. 37—41.

Coupe.
Eaux moyennes.

FIG. 56.

Profil réel de la surface de l'eau suivant l'axe du canal.

Profil du fleuve près de la digue gauche
„ „ „ „ „ „ „ droite.
Différence du niveau.
Pour le niveau des B. E.
Crête de la digue.

FIG. 57.

Digue.
Déversoir.
Ecluse.
Chenal d'accès.
Canal existant.

FIG. 58—62.

Coupe longitudinale.
Longueur utile.
Coupe transversale.

Die Ziffern — **27,140** beziehen sich auf die Oberfläche des Wassers.

Die Ziffern $\boxed{1{,}025}$ bezeichnen die Strömungsgeschwindigkeit per Sekunde.

FIG. 27.

Hochwasser.
Querprofil.
Sommerwasser (Normal 0).
Niedrigwasser.
Neues Fahrwasser.
Altes Fahrwasser.
Absturz.

FIG. 28 U. 30—33.

Siehe Uebersetzungen zu Fig. 26 u. 27.

FIG. 34 U. 35.

Geplante Entfelsung.
Fahrrinne bei Hochwasser.
Leitdamm.
Letztes Project.

FIG. 37—41.

Durchschnitt.
Mittelwasser.

FIG. 56.

Wirkliches Profil der Oberfläche des Wassers in der Achse des Kanales.

Profil des Flusses am linken Damme.
„ „ „ „ rechten „
Unterschied des Wasserspiegels.
Für den N. W. Wasserspiegel.
Kamm des Deiches.

FIG. 57.

Damm.
Wehr.
Schleuse.
Kanal für die Einfahrt in die Schleuse.

FIG. 58—62.

Längendurchschnitt.
Verwerthbare Länge.
Querschnitt.

The figures — **27,140** indicate the comparative levels of the water's surface.

The figures $\boxed{1.025}$ indicate the velocity of the current per second.

FIG. 27.

High water.
Transverse section.
Conventional low water.
Low water.
New channel.
Old channel.
Falls.

FIG. 28 A. 30—33.

See the translation Fig. 26 and 27.

FIG. 34 A. 35.

Projected removal of rocks.
High water channel.
Leading dam.
Latest scheme.

FIG. 37—41.

Section.
Mean water level.

FIG. 56.

Real profil of the water's surface in the axis of the canal.

Profil of the river near the left dam.
„ „ „ „ „ „ right „
Difference of the water level.
For the low water level.
Superior surface of the dam.

FIG. 57.

Dike.
Weir.
Lock.
Channel leading to the lock.

FIG. 58—62.

Longitudinal section.
Length available.
Transverse section.